THE USE OF AN INFORMATION PROCESSING MODEL TO DESIGN AND EVALUATE A PHYSICS UNDERGRADUATE LABORATORY

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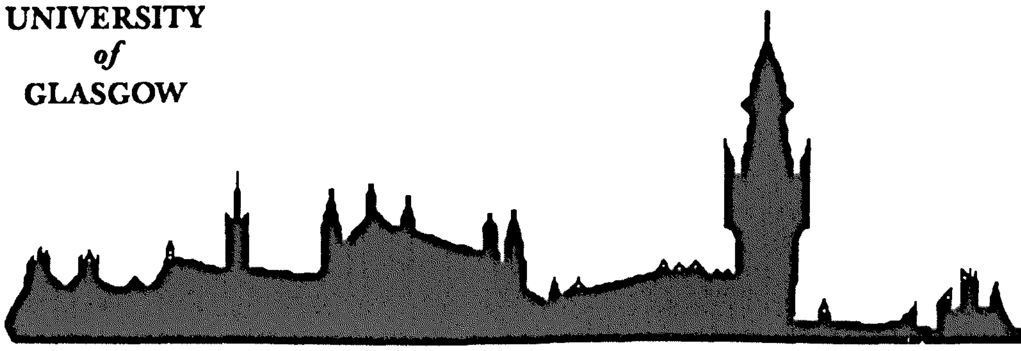

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بسم الله الرحمن الرحيم

(In the Name of Allah the Compassionate the Most Merciful)

I dedicate this piece of work to my

mother the late **SAKINA BEAGUM,** despite the fact that she passed away long ago

she has always been a source of inspiration for me to struggle

and to my father the late **GHULAM SARWAR KHAN,** who always encouraged me

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ABSTRACT

The difficulties in understanding science particularly laboratory learning at undergraduate level was reported by many researchers and authorities. The literature on Science Education contains many examples of teachers' attempts to change laboratory practice to overcome the problem that "much of the student behaviour in laboratories is that of recipe following: they gain hand skills but it is all too possible to follow mindlessly the instructions in a manual". The student will have to cope with many types of learning stimuli that may lead to a state of working memory overload. So it is not surprising that the attempts made to measure the learning outcomes from practical work have produced disappointing results. There are only few systematic, theory-driven measurements reported particularly in the field of physics education.

The psychological background guiding our thinking throughout has been derived from information processing theory. This theory attempts to identify what happens during the acquisition, storage and retrieval stages of learning. A model was presented at the Centre For Science Education Glasgow University, which represents the thinking process in a predictive way.

Using the model, it was decided to concentrate on the principal and inter-linked strategies to improve the laboratory teaching (1) Use pre-labs to involve students in a more 'expert' role, (2) Revise the manual to reduce noise and so reduce overload. Special consideration was given to student perception, the ever-present possibility of working memory overload and the necessity for students to construct for themselves sound and branched mental structures to help them to approach practical bench problems by lateral thinking. The changes to the physics-II laboratory programme were made and evaluated over two years.

This study is an evaluation of the effectiveness of changes made to the undergraduate Physics-II laboratory course at Glasgow University.

To ascertain the success or otherwise of these changes, two separate surveys were

carried out.

The first phase of the research included, (i) improvement in lab manual with few changes in the laboratory procedure, (ii) introduction of pre and post-lab, (iii) analysis of students' attitude to practical work.

The second phase of this research moved to cover the cognitive side, within the perspective of first phase results, it included (i) improvement of pre-lab (ii) meaningful use of post-lab and (iii) analysis of students' understanding of practical work.

The study had two aims, on one side it attempted to provide real understanding to the students of experiments in physics-II laboratory by minimising the noise during learning of experimental work and to increase the students' ability to discriminate signal from noise. On the other hand the researcher intended to find the difference of students' achievement between with pre-lab (N) and without pre-lab (O) work procedure used in the Physics-II laboratory, within the students' cognitive learning style field-dependent/field-independent.

In almost all cases those students who had undergone a pre-lab showed more positive attitude and better performance in post-labs than those who had a pre-lab.

The dissemination of the findings of this research would facilitate:

(a) curriculum planners in working out a psychological curriculum in physics-II (laboratory);

(b) researchers in applying the experimental techniques, used in this study, at other levels and disciplines for cognitive studies; and

(c) working teachers in organising their laboratory teaching effectively.

CHAPTER ONE

GENERAL SURVEY OF LITERATURE

1.1 INTRODUCTION

The work reported here is an investigation of the purpose and effectiveness of practical work in physics at undergraduate level. The information processing theory of learning is used as the psychological model on which the study is based, and the experiments described here were designed with this in mind. The purpose of the experiments was to see whether or not the experience of laboratory work could be made more rewarding by making small but critical changes in procedure suggested by the psychological model. These ideas and procedures are derived from the work of earlier researches in education.

This chapter consists of very general ideas, views, and rules given by scholars, educationalists and scientists. In the light of these ideas and views the researcher intends to clarify his own views about science and science education.

Science education has been the subject of much attention in the past few decades. According to Kempa, (1976), "We have witnessed a steady increase in the number of researches dealing with the learning and teaching of science. Evidence for this is readily provided by the appearance, during this period, of several new journals specially devoted to science education issues and the establishment of science education departments".

1.2 NATURE OF SCIENCE AND SCIENCE EDUCATION

1.2.1 SCIENCE

Science is a way of knowing. The strength of science lies in its ability to ask questions of inanimate or dumb objects and get answers which can be interpreted and built up into a corpus of meaningful knowledge. Science concerns itself with questions which can be answered by reproducible measurement. A patch of colour on a painting emits light of a certain frequency which could be measured with an appropriate instrument answering the question, "What is the frequency of light emitted by the patch?" Other questions such as "Do you like the painting?" cannot be answered by measurement and fall into the area of aesthetics rather then science.

According to Wellington, (1988), "Science has its own unique processes and methods, common to all sciences", He also states that there is no such thing as a true scientific theory. Wood, (1991), remarks "Science requires rational, analytical processes but it also needs creative, intuitive processes. It is a human activity which we share in social groups". Kaufman, (1992), has explained science as, "everything that can be discovered or known is already in existence or embodied in the laws of the universe. Without such a view, there is no Science, no Physics. The discoverer recognises the appearance of the unfamiliar as such and opens the ways to its explanation and to an expansion of human knowledge of the universe around us". In the view of Polkinghorne, (1992), "Our concern as scientists must be to respond adequately to the way the physical world actually is". Wolpert and Harton, (1993), have said, "to incorporate the qualities of worth and desirability into the scientific enterprise is far from sentimental, and it is to the credit of science that this is so; scientists constantly make judgements about the human value of their work". Wolf and Simon, (1993), citing statements of different scholars to explain science: (i) 'Scientific laws and theories exist independent of human existence. Scientists merely discover them' and 'Scientific knowledge more and more approximates truth'.

(ii)'Science like art, religion, commerce, warfare, and even sleep, is based on presuppositions' (iii)'Scientific knowledge is artificial and does not show nature as it really is'. In the view of Lakin and Wellington, (1994), "We all construct for ourselves, from our own training, experiences and philosophy of life a set of unique concepts as to what science means to us. These may be in conflict with some of the views expressed in curriculum documents". Abell, (1994), explained, "Science is discovering and understanding. This is done through manipulating science equipment and things in the real world. Science involves hypothesising, testing and checking". The same author goes on to say, "Science is the investigation and study of how the world works. It deals with the questions of why things are the way they are, what they are, and how they fit into the overall spectrum of life". Hence we do science to make sense of our surroundings. The sense we make and the explanations for how things happen, depend on the theory we use to interpret the results of our comparisons and the theories change with the time.

1.2.2 SCIENCE EDUCATION

In science education we are teaching students to use one form of knowing i.e. the experimental. It has strengths and limitations. It can answer some questions, but not all. It may have some questions to beauty or justice (environment) or use of symbolism, but its main function is that of empirical experiment.

Science education, according to Bernord, (1960), is: (i) a creative intellectual activity leading to unifying concepts of man's natural environment and the application of these concepts to the control of the environment for man's benefit; and (ii) an enterprise which requires man's best efforts to sustain it at an optimum level of productivity. Holmes, (1977), includes general aims and objectives, teaching methods, curriculum theory and philosophy of science as its, specifically, educational features. Crawnthrone and Rowell (1978) remark: "Science education is a well defined, quasi-mechanical process consisting of a number of characteristic stages: (i) observation and experimentation (ii) inductive generalisation: (iii) hypothesis (the formation of general scientific statement or Law) (iv) attempted verification (v) proof or disproof; and (vi) objective knowledge". Heaney, in the Association For Science Education, (1981), talks about education through science, which includes (i) science as intellectual discipline; (ii) science as a cultural activity; and (iii) science and its applications. Stenhouse, (1985), describes the study of how pupils ought to be educated in the science. Wellington, (1988), said, 'Science education is primarily concerned with transmitting a body of inherited knowledge' and at one place he says that "In the 'information age' all that matters is that pupils know how to access information and where to acquire the facts", he also says, "The most valuable part of a scientific education is what remains after the facts have been forgotten". In the opinion of Wood, (1991), the object of scientific activity is to reveal reality. Further he stated that, Science education should be more about the learning of scientific processes then the learning of scientific facts. Lakin and Wellington, (1994), quote Phillida Salmon's statement, "It seems that a particular view and belief about the nature of science may have a considerable influence not only on what science is taught but also on how it is taught". There can be a long discussion about the nature of science education, but from my point of view, Johnstone, (1991), has made a very clear statement of the problem of science education, when he says, "In science education at all levels, the thing which stands out above every thing else is the gross amount of noise which is allowed to surround the signals". This statement is taken to be the basis of this research work. It summarises the main problem of science education and of practical work in particular. Very often, the conceptual message of an experiment is completely obscured by apparatus, or the difficulties faced by the student in operating the equipment. Sometimes unfamiliar background material is needed to understand the experiment and extract the desired result. All these different activities compete for the student's attention while doing the experiment.

1.3 IMPORTANCE OF SCIENCE EDUCATION

Broadly speaking, science education is designed to enable the student to identify and solve scientific problems and to do research in new areas of knowledge. This is implemented by teaching scientific techniques and theories which have been found to be useful in the past.

According to Hurd, (1960), science education has contributed towards many distinguishing characteristics of our civilisation. National security, economic stability, public welfare, and maintenance of a free society are intimately related to the discoveries of science and the applications thereof. The emerging scientific revolution, together with the trends towards industrialisation, demands a programme of science education with new dimensions. Science education serves as fulcrum of change and reform in the education system. In this context Gega, (1966), said: "The importance of science education grows with our changing culture". And the Encyclopaedia of Educational Research, (1952), states, "Science education has its new applications in industry, in control of disease, and in more widespread understanding of scientific discoveries". Holmes, (1977), endorsed these views by saying, "While the spirit of science enquiry and the work of research workers imply that science itself transcends national boundaries, it maintains that systems of science education have their own national specific ethos". Prest, (1977), emphasised that "science education develops appropriate behaviour processes", and Stenhouse, (1985), adds that the self-correcting and self-improving activities, of science education are of importance. In this way science education is thought to be the extension of a more adequate development of children's curiosity through the processes of exploration and learning by experience. It emphasises new perspectives, new problems and satisfaction, and becomes a way of opening new vistas to students, and of finding satisfaction in imaginative and constructive use of their intelligence". In a similar way, Michael, (1975), after classifying science into various disciplines, says that "In the broad domain of science, a central goal is to increase people's reliable knowledge of the natural world. These are present in people's continuing search for understanding of the universe".

Mentioning the importance of science education in terms of meeting energy needs after the year 2000, Cattrell, (1982), remarks, "Every new scientist and engineer who can be educated to recognise this coming great world problem i.e. energy crisis, and expertly trained to increase the supply and conservation of energy, will be one of the world's most valuable citizens in the twenty first century". Stanley, (1982), wrote that Broad balanced science will have many implications in the future for specialist science teachers, industrialists and pupils.

According to Sheikh, (1984), "In science education, the children develop of their own accord a scientific way of observing and thinking, and carry out experiments. It presents new concepts, develops appreciation, including the joy of discovery and desire for study, and develops a strong desire to see the truth. In this way, all human potentials are awakened and developed. The children investigate phenomena in the natural world, notice natural laws, make clear the relation between phenomena and observe nature as a whole. Thus, science education aims at the formation of human character, which includes the formation of view of nature itself. So science education brings the science knowledge necessary for living positively in the world of science and technology".

1.4 HISTORICAL DEVELOPMENT OF SCIENCE EDUCATION

Science education has a very long history. According to Jenkins, (1976), the concept of science education may be traced at least as far back as the phrenologists. It assumes that the methods and techniques of physical science can be applied to educational problems and that experimentation can lead to a body of empirically tested educational theory. Or conversely, according to the Encyclopaedia of Educational

Research, (1952), "the development of educational theory based upon careful study of child growth and development laid the foundation for science education". These two views are interrelated. Lucas, (1965), says during the embryonic period of science education, science was taught with emphasis on the memorisation of facts. Laboratory work and demonstration were not included as a necessary or primary source for acquiring knowledge regarding the methods of the scientist or for the purpose of investigating, clarifying and verifying facts". Encyclopaedia of Educational Research (1950), states, "Science education was introduced in the elementary schools under such titles as elementary science, object lessons and nature study. In the secondary schools these appeared under the title of several more or less discrete, special field subjects as Physics, Chemistry, Human Physiology, Physical Geography, Botany, Zoology, Astronomy, Geology with considerable competition for recognition of these special subjects. General science, Biology, Chemistry and Physics were listed as principal courses in science". Crawthron, and Rowell, (1978), pointed out that the major development of science education in secondary education was initiated, when the 'progressive education association' established a commission on the secondary curriculum. Tracing the development of science education with special reference to Biology science curricula since the 1940's, Meyer, in the Asian Centre of Educational Innovation for Developments, (1982), said "in the years immediately after the Second World War, science education in schools was largely a loose collection of facts, at best held together by the structure of the disciplined learning and the recipe book approach". He further explains., "The first significant change was the realisation emerging through the fifties, that the subject matter could be selected and arranged to enhance the learning of central concepts or 'Big Ideas' of a particular discipline. The subject matter was arranged as learning hierarchies so that 'lesser' concepts led commutatively to understanding of the **Big Ideas**". The Encyclopaedia of Educational Research (5th edition), (1969), says "Science education developed scientific, technical and technological potential. This brought a revolution in science education.

The community looked to public schools for scientists and engineers". Robert, (1960), has noticed, during the fifties and sixties, there was also a strong move to select concepts of greater relevance to everyday life. At this stage, the applied topics were 'grafted on' or treated as 'discovery learning'. This was the period of glossy curriculum packages and centrally developed curricula. The emphasis was on problem solving, inquiry and processes of science. At first 'discovery or inquiry learning' was defined simplistically as being almost synonymous with discoveries of research scientists, but there was a more realistic move towards 'guided discovery', where the steps of problem solving were made overt.

According to the, Asian Centre of Educational Innovation for Development, (1984), "During the late sixties and early seventies, there was a gradual assessment and moderation of the 'discovery approach' and there began to emerge a variety of strategies to bring about a closer match between the methods of teaching and individual styles of learning. However there was a firm commitment to experimental work and to participatory learning. During this period, there began the slow emergence of a relatively new emphasis, which was on values. Questions were asked such as 'inquiry about what', problem solving 'for what purpose'? This approach brings together knowledge, understanding, attitudes skills, and insights in an attempt to understand social values". It further states, "In recent years, several factors, many of them economic and political, have forced science education curricula to become even more directly relevant and appropriate for every day life. This has implied a shift in the method of teaching and learning. Now there are close interactive links between objectives, contents, and methods".

Lewin, (1993), while tracing the development of science education in the developing countries says, "Planning conditions are now very different to those of 1960's when the first large-scale investments in science education took place in most developing countries. Confidence in the role that science education could play in national development has been tempered by widely varying experiences of the extent to which development has taken place and by uncertainties about the benefits that have arisen from expanding access". He also explained that the institutionalisation of curriculum development has meant that most countries have localised their science curricula and have accumulated direct experience of the difficulties of implementing changes in teaching and learning practice. This led to more modest expectations about what can be achieved.

Now the latest trends in science education are the formulation and reformulation, socially oriented approaches, as a growing trend fraught with the loading of 'social utility'. In short science education is reflecting what society is demanding.

1.5 PHYSICS

The World Book Encyclopaedia, (1968), defines "The term physics comes from a Greek word 'phusike' meaning 'nature'. It is a science that tells us the 'how' and 'why' of the non living world. It is concerned with matter and energy". It further explains, "Physics overlaps with living things. Biophysics applies principles of physics to living things. Physical chemistry applies physical principles to the reactions of chemical compounds. Engineering applies the principles of physics to the products of many kinds that man can use. Physics itself depends on Mathematics and Logic".

In the broader sense, physics is that branch of physical science which explains the properties of matter and energy. We know the relationship between apparently unrelated processes with the help of the principles and laws of physics. Physics and its related knowledge explain the facts in clear precise language. Its laws, principles and terminology are stated explicitly in well defined terms so that the scientists all over the world take the same meaning.

According to the Asian Programme of Educational Innovation for Development (APEID), (1978), "It is a quantitative science and in the early period of its genesis, it was studied under the heading of heat, light, sound and electricity. Because of the ever increasing researches in physics, its domain has become so vast that it has become impossible for a man to have command of the subject of physics. Therefore some other branches of physics have emerged such as atomic physics dealing with the nucleus of the atom, solid state physics dealing with matter in the solid state having definite properties and the explanations thereof, Astrophysics and so on.

Wolf and Fraser, (1993), explains that "Physics knowledge, although defined numerically in text books, only finds its true existence within the psyche and understanding of the physicist's mind which makes the connections that turn those facts into an understanding".

1.5.1 IMPORTANCE OF PHYSICS

Physics has left a deep impression on human civilisation. It has played an important role in the present advancement of the world. Sheikh, (1983), has explained that in the 18th century, scientists performed numerous experiments to understand the nature of heat. This led to the development of heat engines. In the 19th century the knowledge of electrical phenomena developed so much so that the use of electrical energy for light, heat, radio, television and the electric motor became widespread. Similarly other investigations led to the discovery of X-rays which not only provided a vital tool for the study of crystals and atomic structure but also paved ways for the revolutionary advancement in diagnosis and treatment of diseases. At present, physics is regarded as the backbone of a country for its progress and prosperity in the field of commerce and trade.

Khim, in the Asian Programme of Educational Innovation for Development, (1978), adds, "Physics is one of the most fundamental of the natural sciences. The body of the knowledge in the form of principles and laws governing many natural phenomena, has become an essential part of the understanding and development of other areas of science such as chemistry, biology, astronomy, meteorology, agriculture, engineering, medicine and geology. No subject deals with more exciting ideas, the application of which has created the modern world of technology. Indeed no area has greater application to everyday living than physics".

According to APEID, (1978), "Television, radio, high fidelity systems, automobiles, supersonic jet flights, lasers, computers and spaceships are a few examples of spectacular technological achievements based on physics principles".

Volger, (1972), describes the importance of physics as, "It is certainly the basic science: it provides the theory behind technology, it is the foundation of technological progress and the basis of many fields of theoretical and applied knowledge". The World Book Encyclopaedia, (1968), states that "Physics, today, is one of the most active and most important of all sciences". Nagy, (Ed), (1972), has said that the importance of physics has also been realised in its teaching and learning processes, because the current college/university population explosion, the exponential growth of information, and the usually inadequate pedagogical background of instructors accentuate the need for higher accuracy and precision in.... Physics teaching and learning. In the opinion of Waldford, (1983), "Physics is allocated more time overall then either biology or chemistry".

In laboratories through out the world, 'Physicists delve' into the mysteries of nature to unearth the secrets of the universe, Endless questions and experiments lead them to discard old theories and propose new ones. Physicists have extended their search into outer space with the developed tools. World Book Encyclopaedia, (1968) and Lawrence, (1996), has explained that, "physics is an essentially human activity of sense making and not a list of thing to be 'got'. We cannot educate people by packing in 'more demand facts'. This cannot be the essence of any course which aims to educate effectively, citizens for the 21st century, equally we can not process information and participate in debate without conceptual schema with which to do so. It therefore behoves us to do a little selection and to choose a few areas of physics to do well. These should be rich in historical links, exemplify physics of work, as a descriptive schema, provide instances of the interaction between theory and experiment in refining our conceptions and be useful tools for thinking".

1.6 LABORATORY TEACHING

The laboratory provides many opportunities for students to talk and write about science. With a little thought and planning and not too much extra effort on the part of students, its activities can be the basis for building communication skills.

In a study of undergraduate physics laboratory classes, Bliss and Ogborn, (1977), examined student perceptions of 'good' and 'bad' experiences and the good stories about laboratories were usually linked to a sense of freedom and satisfaction at achieving some goal.

Kempa, (1986), described the process of practical work in five stages which are widely known as forming a valid and satisfactory framework within which practical skills are to be developed and assessed.

"(a) recognition and formulation of the problem.

(b) planning and designing of an investigation in which the student predicts the results, formulates hypotheses and designs procedures.

(c) carrying out the experiments in which the student makes decisions about investigative techniques and manipulates materials and equipment.

(d) Observational and measuring skills.

(e) analysis, application and explanation in which the student processes data, discusses results, explores relationships, and formulates new questions and problems".

Osborne, (1993), remarks, " What goes on in the laboratory contributes little to student learning of science or to their learning about science and its methods, nor does it engage then in doing science in any meaningful sense. At the root of the problem is the unthinking use of laboratory work". Nuffield educators enshrined the role of practical work through the use of the famous Chinese aphorism 'I hear and I forget, I see and I remember, I do and I understand'. They recognise that children must actively process information if they are to develop their conceptual understanding of science, and they look to practical work as the means of achieving such aims.

Practical activities in a laboratory-type environment have been traditionally an important feature of science.

In physics, practical work has been an important element of most university courses. It has the disadvantage that it is time consuming and expensive in equipment.. Also many experiments are not straight forward in that considerable care is needed to get the apparatus to work properly. However these are features of real-life experimental work. It is also felt that a student has a greater depth of understanding of a topic if he has done an experiment on it. For example in the Michelson Interferometer experiment, he has actually seen interference fringes, and seen how the pattern changes, when he moves the mirror carefully with his fingers. All of this is much more convincing than a description in a lecture or text book.

1.6.1 DEVELOPMENT OF LABORATORY TEACHING

Science literature revealed that during the nineteenth century laboratory teaching achieved its most rapid growth associated with the growth of research schools. So it was that individual practical work was accepted as an essential part of a university course. Until then laboratory instruction had been an isolated activity with support, as the practical work was not compulsory.

The physicist, Owen, (1949), stated that the normal experiment provided too much information for the students and was too abstract, i.e. beyond the student's normal experience. He proposed that not all experiments should be designed to develop scientific method but those which were should give the minimum of information and let the students find out for themselves. The experiments he said, should allow the students to formulate questions, recognise assumptions, apply general principles, interpret data, and make and test hypothesis. Lunetta and Hofstein, (1982), stated that "during the 60's practical science placed emphasis upon the development of higher cognitive skills. Laboratory work acquired a central role as the core of the science learning process, not just a place for demonstration or confirmation. It was thought that the laboratory ought to provide students with opportunities to engage in the processes of investigation and enquiry".

Young, (1968), pointed out that there is a failure to find out what students get from practical work. He thought it valid to present the students with a detailed experimental plan to work through, to teach principles and techniques. However he maintained, from the first year onwards this method should be supplemented by an approach that allowed students to make their own investigations.

Vianna, (1990), explained that , "by the 1970s the laboratory teaching was best done by 'inquiry-discovery' methods and 'problem solving' approaches, in the belief that students could discover for them selves much of what was previously given in lectures". In this period emphasis was on laboratory courses in which students should learn how to deal with systems as they actually behave in the real world, in contrast to the 'ideal' behaviour normally portrayed in the lectures. Johnstone and Wood, (1977), pointed out that, there is an increasing number of researchers applying computers in laboratory simulations and audio-visual technologies as an alternative method of laboratory instructions in the seventies. They examined practical work in secondary schools from the view of teachers and of pupils and showed the practical work should not only be used for theory illustration but that it has its own dimensions as part of the chemistry course, with its own objectives.

Johnstone and Wham, (1982), argued that it is necessary to practise in a systematic manner, the skills and overcoming practical problems. To achieve this they suggested the use of mini-projects, that is small open-ended exercises at any level with the maximum of freedom within the limitation of the present state the student's knowledge.

Hodson, (1985), remarks, "today there is a trend towards education about science, its relevance to society and to the environment and away from education in science". He advocated the idea of the pursuit of science for the sake of knowledge be abandoned to give way to growing concern about social, political and technological issues.

Kempa, (1986), argued that if the components of experimental work in science are to be satisfactorily assessed, it is necessary to evolve at least some broad qualities with reference to which students performance can be judged. Shulman, (1973), Boud, (1980), Swain, (1974), Helingman, (1982), and Kempa, (1986), stated that due to the many different ways in which the aims and objectives of practical work can be formulated, there exists a substantial lack of clarity of purpose in this area.

To conclude, it can be said that practical work involves the application of knowledge the use of theoretical concepts and theoretical evaluation of the results obtained by practical experience. All such interrelationships between practice and theory will continue to raise problems for effective assessment. Another ongoing concern is how to achieve the goals of teaching and learning in the laboratory.

1.7 SUMMARY

It is the age of science. Virtually every aspect of our everyday life is affected in some way by the scientific and technological developments. 'What is science' is not at all equivalent to 'how to teach science'. Most technological development took place before there was any science, for example farming, metal working, building, weaving, dyeing and cooking. In recent years science has preceded technology and provides a base for scientific research and technological development. Science education makes a large contribution in the development of the habit of critical thinking, tolerance and open-mindedness among all people and their effective sensible living. An effective science education programme should be directly linked with the establishment of a infrastructure for research in education, mobilisation of resources for production of equipment and strengthening of the science laboratories and libraries.

The momentum of technological development is itself a source of pressure for teaching science. The importance of practical work is generally agreed upon by the teachers and field researchers despite some disagreement concerning the role of the laboratory courses, their objectives and effectiveness.

Due to different factors which affect the students in practical work situations, this area is viewed as one of the great difficulty by the researchers.

CHAPTER TWO

PSYCHOLOGICAL PERSPECTIVE

2.1 INTRODUCTION

Kamat, (1967), reported that until the Middle Ages psychology was not developed into a separate science. In the earliest days of its genesis, it was regarded as 'science of soul' and its religious aspect was stressed; but gradually it became simply a 'science of mind' studied introspectively and the religious aspect was relegated to the theologians and finally it has become, pre-eminently, a 'science of behaviour'. Morgan, (1961), explained it as a separate form of an 'Experimental Science' having its vast applications in the human and animal world. It is nevertheless, continuing to prosper as an empirical science. Harriman and Philip Lawrence, (1958), "Though it is relatively young, it has many subdivisions, each of which seeks to emphasise a particular area".

Hacker, (1984), described three schools of thought for the intellectual development of this science:

(I) Logical theorist; focusing attention on some form of task analysis which makes the subject matter more digestible for the learners. Gagne's work provides a well known example of this approach. His ideas are particularly important in the work reported here because of their emphasis on prior learning. This is one of the most significant changes introduced in the physics-II lab and is the central modification studied in this thesis.

(II) Pupil's class-room behaviour theorists; stressing the ideas which children bring to the class-room. The work of Novak, (1971), Fensham (1981), and Kempa (1983), Driver, (1983), Gilbert, (1985) provides illustrations of this type.

(III) Cognitive theorists; emphasising internal restrictions on the child's thinking. This school of thought encompasses the Piagetian, and Neo-Piagetian paradigms (Pascual Leone 1969, Case 1977, Scardamalia 1977) and Information Processing views of cognitive development (Ausubel D.P 1973, Klahr and Wallace 1976, Johnstone 1986, El-Banna and Johnstone 1987, Talbi and Johnstone 1990, Ziane and Johnstone 1990, Al-Naeme and Johnstone 1991, Baddeley 1993).

The present study is limited to the third school of thought, "the information processing views of cognitive development". To bridge the gaps between Logical theorist, Behaviour theorists and Cognitive theorists, the researcher will present a brief survey of the different learning theories. Therefore, in this chapter different learning theories have been discussed.

2.2 GAGNE

El-Banna (1987), remarks, "Gagne's learning hierarchy is useful for the researcher to make a bridge between the findings of those who have studied the phenomena of learning primarily in the psychology laboratory, and the situations that involve learning in class rooms/laboratories".

Gagne is one of the psychologists of the second half of this century working in the field of learning. He is basically a 'behaviourist' and emphasises, "what is to be learned".

Gagne, (1968), describes developments and learning as "changes in capabilities" and presumes that "there is no particular point in life corresponding to stage endings and beginnings that determine when a person is ready to learn or to stop any particular capability". According to him: "the present capabilities of individuals are the determinants of what these can start to learn or develop next". In this context Fensham says that "Gagne is concerned not with the process of learning but with the (measurable) state of having learned, which according to Klausmeir, is 'Gagne's

(1970), cumulative learning".

2.2.1 GAGNE'S WORK

Historically Gagne first postulated learning hierarchies and first published his small primary study in 1962, in which he attempted to teach seven children how to find formulas for sums of terms in a number series. Gagne derived a network of elements which he called a hierarchy of knowledge.

Gagne has produced a series of books and dissertations, expanding his views on learning and instruction. White, (1974), outlined three major investigations of Gagne: (i) Gagne and Paradise (1961), used a programmed book to teach 118Ss (subjects), a hierarchy of twenty elements, known as 'learning sets', which led to the element solving linear equations (ii) Gagne, Mayor, Garstons and Paradise (1962), wrote a hierarchy for mathematical subject matter. It had fourteen elements and (iii) Gagne and staff (1965), wrote another mathematical hierarchy.

According to Bergan and James (1976), Gagne emphasises "learning variables", and holds that the intellectual skills are arranged hierarchically.

The behaviour development results from the cumulative effects of learning, which according to Gagne, comprises of (i) conditions of learning (ii) events or processes of learning, and (iii) types of outcomes or capabilities displayed after learning. Gagne divides conditions of learning into internal and external conditions. Under internal conditions, he includes "previous learning and processes". While under external conditions, he includes a variety of factors such as stimulation by others to recall and inform rehearsal techniques, transfer and motivation.

Gagne's five categories of what is learnt have briefly been explained by Bergan and Dunn (1976), these are:

1. <u>Motor skills</u>: These are processes producing experts, in rapid and accurate physical performance. These require practice. Tying shoes and printing letters are the

examples of this category;

2. Verbal Information: This category includes learning and retention of facts, principles and generalisations;

3. Intellectual Skills: These are intellectual capabilities for the performance of a task and involve discrimination concepts and rules used in mastery of academic material;

4. Cognitive Strategies: These are intellectual skills such as conserving, focusing and are directed towards self management of learning and thinking;

5. Attitudes: These are affective reactions derived from sets of beliefs, intentions and so on.

In his early work Gagne, (1965), suggested a hierarchical list of eight categories of learning. This list, in the opinion of Romiszowiski (1981), is hierarchical in the sense that (i) it proceeds from very simple conditioning type learning, up to complex learning, such as that involved in problem solving and (ii) lower levels of learning are pre-requisites to higher levels. This is the whole web of his framework and is given below.

TYPE-1: Signal Learning; The individual learns to make a general diffused response to a signal. This is the classical conditioned response of Pavlov, (1972). The characteristic of this type is that the stimulus and the response must be closely associated in time: the stimulus precedes the response, and it will not produce the desired learning, if it takes place too many seconds before the response.

TYPE-2: Stimulus Response Learning; The learner acquires a precise response to a discriminated stimulus. Gagne gives the following characteristics of this type of learning:

(a) The learning is typically gradual: some repetition of the association between the stimulus and the response is usually necessary.

(b) The response becomes more precise as the repetition takes place.

(c) The controlling stimulus becomes more precise.

(d) There is reward or reinforcement, for exhibiting the required response and there is no reward when the behaviour is in correct.

TYPE-3: Chaining; What is required is a chain of two or more stimulus response connections. Characteristics of this type of learning are:

(a) The individual links in the chain must be established first.

(b) The events in the chain must occur close together in time,

(c) If both other two conditions are satisfied, learning a chain is not a process, but occurs on a single occasion.

TYPE-4: Verbal Association; It is the learning of chains that are verbal. Basically, the conditions resemble those for other (motor) chains. However the presence of language makes this a special type because internal links may be selected from the individual's previously learned repertoire of language. The conditions for effective learning, according to Gagne are:

(a) Each link must be established previously.

(b) Response differentiation must have taken place.

(c) A coding connection must be established.

TYPE-5: Discrimination Or Multiple Discrimination Learning; The individual learns to make multiple differences identifying responses to as many difficult stimuli, which may resemble each other in physical appearance to a greater or lesser degree. Although the learning of each stimulus response connection tends to interfere with each other's retentions. The conditions for this type of learning are:

(a) Necessary stimuli/response must already be established.

(b) Interference from conflicting stimuli must be reduced to a minimum.

TYPE-6: Concept Learning; The learner acquires a capacity for making a common response to a class of stimuli that may differ from each other widely in physical appearance. He is able to make a response that identifies an entire class of objects or events.

The conditions for this type of learning are:

(a) Necessary stimuli responses must be established.

(b) A variety of stimuli must be presented, so that the conceptual property, common to all of them, can be discriminated.

(c) The learning of a new concept may be gradual, because of the need for a variety of stimuli.

TYPE-7: Rule Learning; In the simplest terms, a principle is a chain of two or more concepts. It functions to central behaviour in the manner suggested by a verbalised rule of the form. "If A then B", where A and B are concepts. However it must be carefully distinguish from the mere sequence "If A then B", which of course may also be learned as type-4.

The conditions of this type of learning are:

(a) The concepts to be linked must be clearly established.

(b) The learning of a rule can take place on a single occasion.

TYPE-8: Problem Solving; It is a kind of learning that requires the internal events usually called thinking. Two or more previously acquired principles are somehow combined to produce a new capability that can be shown to depend on higher order principles.

The conditions for this type of learning are.

(a) The learner must be able to identify the essential features of the response that will be the solution before he arrives at the solution.

(b) Relevant rules are used and recalled.

(c) The recalled rules are combined so that a new rule emerges.

For Gagne, the objectives of instruction are intellectual skills or capabilities that can be specified in operational terms, can be analysed, and then can be taught. In this context, Romiszowiski, (1981), says "Objectives clearly stated in behavioural terms are the cornerstone of Gagne's position". To him psychology is "successful in suggesting ways of teaching only when objectives have been made operationally clear" otherwise the psychologist can be of little assistance.

El-Banna (1987), in his PhD thesis quotes, Gagne (1977), in these words, "Gagne reviewed various theories of learning and he observed that there had been frequent recourse to certain typical experimental situations to serve as prototypes of learning which represent a variety of kinds of learning". For example Thorndike was a pioneer in using animals for experiments on learning, then Guthrie, Hull and Skinner tried to follow him by using animal behaviour as the basis of their ideas. Pavlov studied reflexes. Ebbinghus carried out a set of experimental studies of learning and memorisation. Kohler as one of the Gestalt team, was studying insightful learning in animals.

2.2.2 GAGNE'S FOLLOW-UP STUDIES

Many psychologists and educationists have carried out follow-up studies of Gagne's hierarchical approach. White, (1971-1974), in his different articles, '(a) Research in to learning hierarchies, (1971), (b) A limit to the application of learning hierarchies, (1973), and (c) Past and future research on learning hierarchies' (1974), has given the details of follow-up studies on Gagne's work and identified the following areas of research on learning hierarchies:

(i) Investigation of validity of learning hierarchies;

(ii) Use of hierarchies in mediating vertical transfer;

(iii) Generalisability of a valid hierarchy;

(iv) Presence of hierarchies in many subject areas;

(v) Mastery of learning of intellectual skills;

(vi) Retention of learning of intellectual skills;

(vii) Development and evaluation of instructional material.

Howe, (1974), has also given a follow-up study on the acquisition and growth of the concept of liquid on the basis of five tasks. It seems that Howe and White are agreed with these areas of research in learning hierarchies.

The above mentioned areas of research and follow-up studies have established the importance of Gagne's hierarchical approach. Soulsby, (1975), summarises it as follow s "a growing volume of studies testify to the increasing popularity of this type of learning and, in particular, of the notion of learning hierarchies".

2.2.3 GAGNE'S HIERARCHIES AND BLOOM'S LEVELS

Stone (1972), has indicated a clear correspondence between the Bloom and Krathwoll's proposals and the Gagne hierarchies. In this context Stone remarks that "the lower level learning of the facts type in Gagne's model, relate to the learning of facts and objectives in the lower levels of Bloom's taxonomy, i.e. they indicate the type of learning likely to be required to achieve the objectives at level I of Bloom's taxonomy". He further says, at the higher level, principle learning and problem solving are clearly related to such objectives, as 'the ability to plan a unit of instruction for a particular teaching situation' (Bloom level 5.30) or the ability to indicate logical fallacies in arguments (Blooms level 6.10). In this way he concludes, "To a great extent the two approaches are complementary. The Bloom's taxonomy helps to classify the goals and provides a tool for the effective analysis of objectives, while the Gagne scheme provides the same for learning behaviour. In this regard Krathwoll, (1972) remarks: "Gagne's categories are a blending of behaviouristic psychology and cognitive theory.

2.2.4 CRITICISM OF GAGNE'S LEARNING HIERARCHIES

Gagne's learning hierarchies have been widely criticised. Soulsby, (1975), remarks, "The most general objection which can be made to Gagne's theory is that particular examples of learning were generalised to become prototypes representing (or rather misrepresenting) the domain of learning as a whole. His description does not cover the affective domain at all, nor can it adequately explain the highest and the most, complex varieties of human performances. Both of these are, in themselves, crippling defects in a theory of learning". Soulsby, is supported by White (1973), White and Gagne (1974) and Gagne, himself (1968). White, (1974), has identified five weaknesses in the previous work done during the investigation of the validity of learning hierarchies. He says, "(a) The elements that comprised the hierarchy were often loosely defined. (b) Often only one question was used for each element to test whether Ss have learned it or not.

(c) The studies lacked a proper index that could be used to decide whether connections between pairs of elements could be accepted as hierarchical or not;

(d) In some studies, the elements of the hierarchies were taught to a group of Ss who were tested on all the elements together after the teaching and the Ss were only tested on their possession of the elements;

(e) In a few studies, a small number of Ss were used, which meant that quite a substantial proportion of people in the population from which Ss were drawn could behave in ways contrary to that required by a valid hierarchy and remain undiscovered through not being drawn into the sample".

He has further suggested the following nine stages for the validation of hierarchy.

"**Stage-1**: Define in behavioural terms the element that is to be the pinnacle of the hierarchy;

Stage-2: Derive the hierarchy by asking Gagne's question; 'What must the learner be able to do in order to learn this new element given only instructions of each element downwards ?"

Stage-3: Check the reasonableness of the postulated hierarchy with experienced teachers and subject matter experts;

Stage-4: Invent possible decision of the element of the hierarchy so that very precise definitions are obtained;

Stage-5: Carry out an investigation of whether the invented decisions do, in fact represent different skills;

Stage-6: Write a learning programme for the elements embedded in its test.

Stage-7: Have, at least, 150 Ss, suitably chosen, work through the programme answering the questions as they come to them;

Stage-8: Analyse the results to see whether any of the postulated connections between elements should be rejected;

Stage-9: Remove from the hierarchy all connections for which the probability is small, say 0.05 or less.

After going through these stages, the question is whether the hierarchy could be used in every subject or could it be useful for some subjects only. This leads to the application of aspects of Gagne's learning.

2.2.5 APPLICATION OF GAGNE'S HIERARCHY

According to White, (1971), Learning hierarchies have wide application in the learning process. Deming supports White's statement in these words "....learning hierarchies would provide a more efficient means for selecting, ordering and teaching curriculum than any other approach presently used". Further he says, "Through the use of learning hierarchies, we can trace step by step incrementation of learning by requiring the student to exhibit the performance specified in each succeeding objective".

White, (1973), and Deming, (1975), talk about the effective use of the hierarchy.

Deming says; "The hierarchy approach has been demonstrated most successfully with in relatively short components of curricula such as a single unit". White corroborates this by remarking, "the strong form of Gagne's hypothesis of learning hierarchies is supported for intellectual skills. Much of the subject matter of mathematics and the physical sciences is of this type, so learning hierarchies should be particularly valuable in those subjects. Intellectual skills appear to be more difficult to identify and define in other subjects then physical science".

Klausmeir, (1978), remarks about Gagne, that "The learning hierarchy in the building blocks in developing instrument sequence to teach any particular task, Gagne presumes that most learning tasks can be analysed into learning hierarchies". Bergan and Dunn (1976), acknowledge that the significance of Gagne's work is "that it makes it possible to consider the study of thinking within a learning theory frame work. Furthermore it extends learning theory concepts to long time segments, that in the past have been regarded as within the domain of the developmentalists. Through the influence of Gagne's work, education seems to be moving close to the goal of markedly affecting the development of intelligence through instruction". It is in this context that Romiszowski (1981), remarks "In a recent book (Gagne 1974), he has further extended his model to include yet more types of learning .... closer to the cognitive school ... much closer to the cognitive position adopted by Bruner".

2.2.6 CONCLUSION

The description of Gagne's work, his educational contribution and the criticism against him allow the researcher to draw the following conclusions:

1. Learning hierarchies are concerned with intellectual skills.

2. Learning hierarchies are not a theory of learning, but these are techniques or a net work.

3. Learning hierarchies identify prerequisite skills.

4. Learning hierarchies do not identify the external conditions. They are concerned with the internal conditions of learning.

5. Learning hierarchies represent a useful system of organising learning.

6. Learning hierarchies propose that what is lacking is concrete knowledge, rather than certain logical processes.

7. Learning hierarchies do not represent everything that can be learned, not even everything that is learned.

8. For each element in a hierarchy, more than one question is required to validate it.

9. In a learning hierarchy, the order relationship is important. The position and directionality are also considered to be important.

10. Gagne's model of a learning hierarchy is based on the learner's prior knowledge.

2.3 AUSUBEL THEORY OF MEANINGFUL LEARNING

Ausubel ideas are significantly important in the work reported here because of his emphasis on meaningful learning, it includes pre-knowledge and the knowledge develop in the learner's cognitive structure (post-knowledge). This is another important and most significant change introduced in the physics-II laboratory and is the second central modification studied in this survey.

Ausubel's cognitive learning theory has been found to be a useful guide for learning events. The key concepts involved in the theory are a guide for teachers to improve teaching and learning.

As an educational psychologist, Ausubel was concerned with prior knowledge as a factor influencing learning. And it is the main emphasis of this study reported here. The principal idea in Ausubel's theory is that the most important factor influencing learning is the quantity, clarity and organisation of a learner's present knowledge. This present knowledge, which consists of facts, concepts, propositions, theories and the raw perceptual data which the learner has available to him at any point in time is referred to as his cognitive structure.

Ausubel, (1968), stated that "If I had to reduce all of educational psychology to just one principle, I would say this: ' the important single factor influencing learning is what the learner already knows'. Ascertain this and teach him accordingly".

In this theory there are two fundamental, independent dimensions of the learning process.

(i) the information presented to the learner by reception or discovery and

(ii) assimilation of this information into his existing cognitive structure by meaningful or rote learning.

Novak, (1980), agreed that Ausubel's theory is applicable and more powerful for science and mathematics education than the developmental psychology of Piaget.

2.3.1 MEANINGFUL LEARNING

Ausubel, (1966), says that "Meaningful learning takes place if the learning task is related in a non arbitrary and nonverbatim fashion to the learner's existing structure of knowledge". According to the cognitive structure theory it is a framework of knowledge stored in the learner's mind that grows and develops towards formal reasoning. Novak, (1978), added "learning occurs when the learner makes a conscious effort to determine the key concepts in new knowledge which relate to other concepts".

Ausubel, (1973), has explained that for a meaningful learning, three conditions must be met.

(i). The material itself must be able to be related to some hypothetical, cognitive structure in a non-arbitrary and substantive fashion.

(ii). The learner must possess relevant ideas to which he can relate the material.

(iii). The learner must possess the intention to relate these ideas to cognitive structure in a non-arbitrary and substantive fashion.

Millar, (1989), remarks, "the constructivist view on knowledge acquisition suggests that meaningful learning involves integrating new knowledge with pre-existing schemata, and the reconstruction of meaning rather than the mere accumulation of new facts".

West and Fensham, (1974), state that "meaningful learning occurs when the learner's appropriate existing knowledge interacts with the new learning. Rote learning of the new knowledge occurs when no such interaction takes place".

Ausubel, (1968), discussed kinds of meaningful learning ranging from representational learning to discovery learning.

Representational learning can take place as the lowest level of meaningful learning and concerns the meaning of the symbols or single words which refer to the objects. Propositional learning is that which concerns the apprehension of the meaning of ideas as groups of words combined into propositions or sentences.

2.3.2 ROTE LEARNING

Ausubel makes a strong distinction between rote and meaningful learning where rote learning results in a arbitrary, verbatim incorporation of new knowledge but meaningful learning consists of the assimilation of the new knowledge in the learner's mind.

Ausubel, (1973), says "meaningful and rote learning are not dichotomies, however learning will be increasingly rote to the extent that:

(a) the material to be learned lacks logical meaningfulness,

(b) the learner lacks the relevant ideas in his own cognitive structure,

(c) the individual lacks a meaningful learning set.

Any one of those conditions by itself will produce conditions likely to lead to rote learning.

West and Fensham, (1974), state that "Rote learning is considered to be the opposite of meaningful learning. Rote learning occurs when no such interaction takes place as the interaction takes place in meaningful learning".

Novak, (1978), writes "the process in cognitive structure differs from Piaget's concepts of assimilation, but results from growing differentiation and integration of specifically relevant concepts in cognitive structure". El-Banna, (1987), remarks "Rote learning represents one end of the learning characterisation continuum scale, and meaningful learning represents the other end".

2.3.3 DISCOVERY LEARNING

Ausubel, (1966), states that "the principal content of what is to be learned is not given but must be discovered by the learner before he can internalise it". Orton, (1987), agreed that discovery is important in promoting learning with young children. Novak, (1980), added that discovery learning occurs primarily with very young children in the process of concept formation. Bruner, (1960), advocated discovery learning in mathematics. He said that discovery encouraged a way of learning mathematics by doing mathematics and it encourages the development of a view that mathematics is a process rather than a final product.

Bruner is of the opinion that, because one could not wait for ever for pupils to discover and the curriculum could not be completely open and it had to be guided to some extent.

Ashlock and Herman, (1983), explaining the advantages of discovery learning maintained that it ensured the meaningful learning, since the pre-requisite knowledge must be activated before the discovery activity can progress. It also presents situations in the same ways as these in which the learning will need to be used subsequently. Discovery promotes the learning not only of the principle itself but of general strategies for the investigation of problems, and if discovery is successful, it is highly motivating.

2.3.4 RECEPTION LEARNING

Ausubel, (1966), explained that "the principle content of what is to be learned is presented to the learner in more or less final form". The information is provided directly to the learner and it does not involve discovery.

Ausubel considered that both discovery and the reception learning method could be classified either as meaningful or as rote learning.

El-Banna, (1987), "In reception learning, the content is presented to the students, either by teachers or by written materials, in its final form. All that students have to do is to incorporate this content in to their cognitive structure to learn it and remember it".

SUBSUMER: Ausubel proposed the idea of a subsumer as a point of attachment for new knowledge. Novak, states that (1978), "Any concept, principle or organising idea that the learner already knows that can provide association or anchorage for various components of new knowledge is a subsumer". West and Fensham, (1974), state that "The process of meaningful learning results in subsuming of new knowledge".

Novak, (1978), goes as far as to suggest that subsumption does not occur in the basic stage of development but rather results from growing differentiation and integration of relevant concepts in cognitive structure. New knowledge is linked to specially relevant concepts or propositions and this process is continuous. Major changes in meaningful learning occur, not as a result of a stage of cognitive development, but rather as a result of growing differentiation and integration of specifically relevant concepts in cognitive structure.

Orton, (1978), explained that if the subsumers or anchoring ideas or concept were there (in the pupils cognitive structure) the pupil was effectively ready. It seems that the Ausubel view of readiness/subsumer is close to that of Gagne. Shulmen (1970), supports this, he states, "Ausubel was in fundamental agreement with Gagne in that the key to readiness was pre-requisite knowledge".

MacGuire (1981), explaining subsumption says, "During the process of subsumption both the anchoring concept and the new knowledge are modified but retain their separate identities. As a result of the continuity of modification and elaboration in the learner's cognitive structure, meaningful learning occurs".

ADVANCE ORGANISER: Preparation of the cognitive structure of the learner for a new learning task will facilitate the learning. This is the idea developing from Ausubel's theory.

Ausubel proposed a pedagogical strategy of using an advance organiser. West and Fensham, (1974), describe this as "a verbal statement, presented to the learner before the detailed new knowledge". Novak, (1984), says "The organiser is a small learning episode that is more general and more inclusive than the learning material that follows and that it is perceived by the learner to serve as a cognitive bridge between what he or she already knows and what is to be learned". Further Novak, (1971), maintains that the advance organiser facilitates knew knowledge, when the material is completely novel and no relevant concept exists in the learner's mind.

If the child is not ready in the sense of having appropriate subsumers, there is the possibility of using an advance organiser to bridge the gap. Ausubel, (1973), adds "The main goal of the advance organiser is to bridge the gap between what the learner already knows and what he needs to know". When there are no relevant items in the learner's cognitive structure then Novak, (1978), says, "it is unlikely that any type of advance organiser will function, for the organiser itself must be meaningful to the learner".

2.3.5 FOLLOW UP STUDIES OF AUSUBEL'S THEORY

Several investigations are reported stemming from Ausubel's theory.

West and Fensham, (1974), have pointed out the obvious relation of Ausubel's theory to the teacher's task making it eminently worthy of consideration and deserving wider acceptance than any other theory.

Ausubel's theory is based on the part played by the learner's prior knowledge and how the new knowledge interacts with it, to build his cognitive structure. The subsumers that the learner uses for subsumption may not be those obtained by a logical task analysis and may not be the same for all learners. Hence, the task of deciding what prior knowledge is needed to act as subsumers, and the task of preparing a test to measure them, are very difficult.

Shavelson, (1972), reported that the cognitive structure of learners undergoes changes during instruction in physics. Key facts and concepts were interrelated more closely at the end of the instruction than at the beginning. The learners cognitive structures correspond more closely. Entwistle and Huggins, (1964), reported that, when two closely related concepts are taught together, the student learns less about either concept than they would if the concept were presented separately. The concepts seem to interfere with the meaningful learning process.

Kempa and Nicholls, (1983), supported Ausubel's theory in the contribution of prior knowledge subsumers to the learning process. They tried to find a relationship between students' problem solving ability and their cognitive structures. They found that good problem-solvers have a more complex cognitive structure then poor problem solvers. Ring and Novak, (1971), reported the same results after having investigated the effect of students' existing cognitive structure on the learning of new material in the light of their achievement in college chemistry.

2.3.6 CONCLUSION

The description of Ausubel's work, educational contribution and follow-up studies enable the researcher to draw the following conclusions:

1 Ausubel interpreted learning as a continual modification and amendment of the learner's cognitive structure.

2. Understanding the learner as an individual and using progressive differentiation and integrative reconciliation in teaching and learning is the core of Ausubel's theory.

3. The understandability of learned material, the learner's adaptation of meaningful material and the harmony of knowledge in the cognitive structure may play a critical role in anchoring successful teaching and learning.

4. Ausubel accepted the idea of assimilation and accommodation and referred to concrete and formal stages but he did not accept the full implication of Piagetian stages.

5. Novak, (1979), "The concrete experience must be represented in a context that helps to build a conceptual frame work. Then and only then, will the early learning form a base for the assimilation of experiences that come later, experience that may involve direct observation or the report of observations made by others.

6. Ausubel has a similar view to that of Gagne, in terms of learning hierarchies, but he takes a more extreme position than Gagne about content knowledge rather than learning to think. However Ausubel adds to the learning hierarchy the principle of the advance organiser. Both reception and discovery learning can be meaningful or rote.

7. The theory is experimentally difficult to investigate.

2.4 SUMMARY

In this chapter we have discussed Gagne's hierarchies and the theory of meaningful learning developed by Ausubel. They address somewhat different aspects of learning but complement each other and overlap on some areas.

There are some generalisations with which Gagne and Ausubel seem to agree.

Both tried to explore the child's ability to solve problems, from a different philosophical points of view.

Gagne agreed that a child develops intellectual capabilities which are as a result of the interaction between the child and his environment. The acquisition of these capabilities is sequential.

Ausubel has also agreed that a child's cognitive development occurs in stages and are age-dependent and these stages happen according to the differentiation and integration of subsumers.

Gagne learning hierarchies are not a theory of learning, but are techniques or a networks. Ausubel presented a theory of meaningful learning.

Gagne and Ausubel agree that prior knowledge can influence learning.

CHAPTER THREE

PSYCHOLOGICAL BASES OF THIS RESEARCH

3.1 INTRODUCTION

Theories divide the cognitive system into components and explore the way in which these components encode, transform and manipulate information. The model it provides attempts to identify what happens during the acquisition, storage and retrieval of information. And the use of information involves a number of separate stages. The information processing theory has also been concerned with studying the difference between a skilled expert and a novice performing some task. Specifically what it implies about laboratory science learning is that there is a considerable difference in the knowledge and strategies that an expert and a novice possess and this difference will affect such factors as how a task is approached and what information is sought.

According to Johnstone, (1991), individual differences in learning and teaching any subject matter is one of the most striking phenomena. The Cognitive style field-dependence/field-independence, and its effects upon the performance differences in learners and its learning implications with special reference to the science laboratory learning are discussed and accepted as a significant concern in the development of instructional material.

When this is linked with a predictive model of learning science, interesting relationships emerge.

3.2 MEMORY

Parkin, (1995), while tracing the history of memory, found that the dominant approach to human memory research stems from the tradition established by Herman Ebinghaus, He realised that the human memory could not be investigated rigorously unless every effort was made to exclude the influence of extraneous factors on the outcome of experiments. Ebinghaus realised that a major contaminating factor could be the prior knowledge that a subject brings to an experiment. Bartlett, (1932), remarks, "human memory can be properly understood only by getting subjects to learn and recall material that means something to them".

As defined in Webster's New World Dictionary, (1980), memory consists of "the power, act, or process of recalling to mind facts previously learned or past experiences". Neisser, (1982), has examined a case, which illustrates the abilities of human subjects to distort and bias the retrieval of memories that are meaningful to them.

Baddeley, (1993-94), has explained that the use of a single term might seem to suggest that memory is unitary, "in fact it is not one system but many". The systems range in storage duration from fractions of a second up to a life time, and in storage capacity from a tiny buffer store to the long term memory system that appears to exceed in capacity and flexibility the largest available computer. Thus the memory does not comprise a single entity, but rather consists of a range of different systems which happen to have in common the capacity for storing information.

Ashcraft, (1994), seems to support the Baddeley explanation; in his opinion "memory means the mental processes of acquiring and retaining information for later retrieval and the mental storage system that enables these processes".

Hence memory is referring to three kinds of mental activities, initial acquisition of information, subsequent retention of the information and then retrieval of the information.

3.3 WORKING MEMORY

Baddeley, (1994), explained that, "working memory is the term used to describe the alliance of temporary memory systems that play a crucial role in many cognitive tasks such as reasoning, learning and understanding".

The term short term memory is used by Atkinson and Shiffrin, (1968), White, (1993) and some other researchers in the presentation of their work. The term working memory is used by Baddeley and Hitch, (1976), Anderson, (1983), Johnstone, (1988), and they are substituting short term memory with a single unitary store into working memory with a number of sub-systems.

In the multi store model of memory, presented by Atkinson and Schifin, (1968), short term memory is regarded as one of a number of different kinds of memory stores. They assumed that the short term memory store acted as a working memory which is a system for temporarily holding and manipulating information as a part of wide range of essential cognitive tasks such as learning, reasoning and comprehending.

According to Baddeley and Hitch, (1977), and again Baddeley, (1994), the working memory is a broader conceptualisation of our short term immediate memory abilities consisting of an attentional control system, central executive and two major slave systems one verbal and other is visual.

The Central executive is used to deal with tasks of a cognitively demanding nature, since it allocates attention to inputs and directs the operation of the other components. It is the most important of the components. The central executive has a strictly limited capacity being a very flexible system that can process information in any sensory modality in a variety of ways. It can also store information over brief periods of time.

The **Verbal** rehearsal loop can be regarded as an articulary loop. It organises information in a temporal and serial fashion, and it deals with verbal information in terms of its articulation. It has a time based capacity. **Visual** is similar to the verbal being able to handle more than one stimulus at a time and has the ability to rehearse information. It deals with visual and spatial information rather than the phonemic information used by the articulatory loop. Further they explained that Primary acoustic store receives direct auditory input. Visual input can only enter it indirectly after being converted to phonological form.

Baddeley, (1993), remarks, "short term memory represents not one but a complex set of interacting sub systems which I shall refer to as working memory". So working memory fulfils the same functions as short term memory in the Atkinson and Shiffrin model.

Johnstone, (1984), has made a very clear distinction between short term memory and working memory. According to him, if someone is subjected to memorise a set of numbers such as new telephone numbers then gives them back in the same order within seconds, there is no processing and the space is used completely as a short term memory. But in another case if some one is subjected to receive input in the form of numbers and then asked to sum the first and the last and multiply by the middle number, processing now begins to operate and the space is called in this case not short term memory but a working memory, which can be defined as "that part of brain where we hold information, work upon it, and shape it, before storing it in the long-term memory for further use". Baddeley and Hitch, (1977), and Johnstone, (1988), agreed that working on a function involves the conversion of new material selected through perception into a comfortable form for storage.

There is now almost universal agreement found that it is much more realistic to assume that working memory consist of several relatively independent processing mechanisms rather than a single unitary short term store. It seems reasonable to treat attentional processes and short term store as part of the same system, as it has already been assumed to be a 'SHARED SPACE' by Johnstone, Sleet and Vianna, (1994).

3.3.1 WORKING MEMORY CAPACITY AND CHUNKING

Jacobs, (1887), attempted to measure the short term memory directly. He devised the technique that has become known as the memory span procedure in which the subject is presented with a sequence of items, often numbers, and required to repeat them back verbatim. The sequence typically begins with one item and is gradually increased in length to a point at which the subject consistently fails to repeat the sequence correctly. The point at which the subject is right 50% of the time is designated as his or her memory span. In terms of short term memory capacity, Miller, (1956), showed that immediate memory span was determined by number of CHUNKS rather than number of items, averaging about 7 plus minus items (chunks) of information which can be stored in short term memory at a time. Afterwards researches in the same area confirmed his findings. Baddeley, (1994), explained that a CHUNK is an integrated piece of information, where remembering part of it will help to remember the next.

Central processor/M-Processor/ or the mental capacity, vary with age and biological maturation factors. Scardamalia, (1977), and Case, (1977), found that there is maximum number of items of information, discrete CHUNKS or schemes that a subject can hold in his mind while working on a problem. Baddeley, (1994), says, "it is therefore responsible for holding items of information for a limited time and carrying out various processing operations".

Miller, (1956), Anderson, (1983), Baddeley, (1986), Johnstone and El-Banna, (1986), presented working memory space as a busy area of the brain into which selected sensory input comes into contact with material from long term memory and undergoes a variety of processes. The new input is scrutinised, shaped, interpreted, linked to the existing understanding and sent for store in long term memory. Johnstone and Al-Naeme, (1991), stated, "There is a limitation on the space available for all this conscious processing and not everyone has the same space. The space is where a set of functions are dynamically taking place, selection of input, temporary memorisation of sensory input, appeal to long term memory for complementary input, searching and matching, sense making, and sending of 'shaped' information to long term memory".

There is no agreement found about the working memory space in an individual, whether it is a fixed entity for each individual from birth which is used more efficiently with age and experience or whether it expands to a maximum with age.

3.3.2 INFORMATION PROCESSING LOAD

Baddeley, (1994), assumed that "The larger the number of digits being held, the greater the amount of working memory capacity that should be absorbed, and the greater interference with reasoning or learning performance". While reporting the results of an experiment Baddeley, Lewis, Eldridge, and Thomson, (1984), explained that digit span during retrieval from long term memory was found to have no effect on accuracy of performance although it did produce an increase in retrieval latency. The requirement to remember and recite a six-digit number had no effect on the accuracy of recalling or recognising lists of words, whether tested by free recall or paired-associate learning.

The task difficulty or information processing load is a factor which is important in determining a learner's success on a task. Scardamalia, (1977), defined "the information processing load as the maximum number of schemes the subject must activate simultaneously, through an attentional process, in the course of executing a task".

Bereiter and Scardamalia, (1979), and Johnstone, (1988), explained that the information processing load (some researchers refer to this as M-demand or Z-demand) depends upon the strategy by which the subject finds the solution. The same task, may have a different information processing load depending upon the most efficient strategy that is likely to be available to subjects. working through this strategy step by step and calculating at each step the number of schemes that must be activated gives some measure of the information processing load of the task.

Niaz, (1988), says that "the quality of a solution depends on the information processing load which produces failure or success or back down and that the logical capabilities of subjects can be grossly misjudged if we do not present a task in its lowest possible load corresponding to its logical structure". Similarly Scardamalia explained the **Horizontal decalage:** the phenomenon of passing certain tasks and failing others with the same logical structure, in terms of information processing load which increases with the logical complexity of task, but may also vary within tasks of the same logical structure.

Pascual-Leone, (1969), conducted task analyses in terms of the amount of information required by a task. However it is difficult to determine the information processing load of a task without knowing the strategy employed by the solvers. Niaz, (1987), suggested that it is possible to change the information processing load of an item without changing its logical structure. This could avoid over load on student working memory space.

3.4 INFORMATION PROCESSING THEORIES AND MODEL OF LEARNING

The information processing approach generally reflects the ways in which the memory system encodes, stores and retrieves information. To study cognition researchers borrowed ideas from communication theory, the theory of computation, artificial intelligence and linguistics.

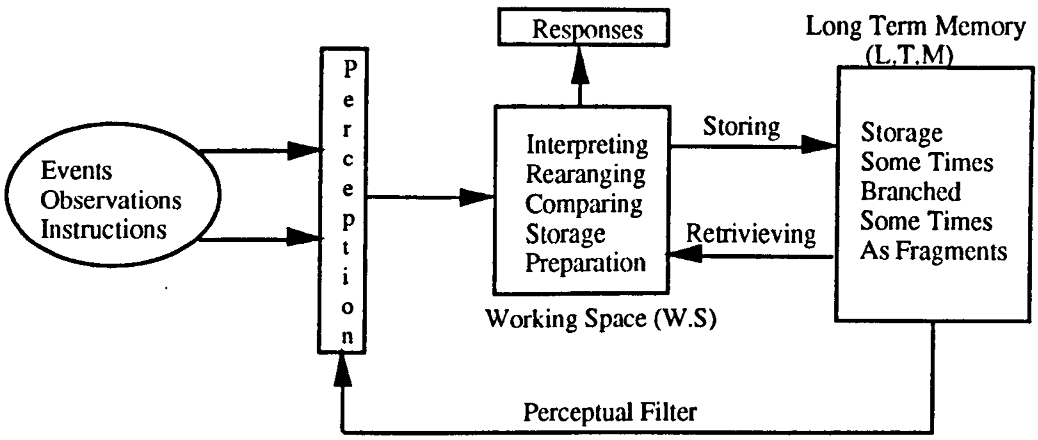
The information processing theories have been concerned with studying the differences between a skilled expert and a novice performing some task. There is a considerable difference in the knowledge and strategies that an expert and a novice possess and this difference affects such factors as how a task is approached and what information is sought. The experts usually have available a variety of problem solving strategies not available to novices. It was noted in the researches by Johnstone, (1987), El-Banna and Johnstone, (1987), Talbi and Johnstone, (1990), Johnstone, Sleet and Vianna, (1994), Al-Naeme and Johnstone, (1995), that knowledge has to be reconstructed as it passes from one person to another and what we already know and understand controls how we interpret, process and store information.

Within the perspective of information processing theories many models have been proposed for a long time. James, (1890), has called the memory system supporting consciousness primary memory, to distinguish it from secondary memory. During 1960's there was a massive growth in the use of computers and increased public awareness of how computers worked. This led directly to a **multi store model** presented by Atkinson and Shiffin, (1968). This model, depicts memory as entailing the flow of information between three interrelated stores, the sensory store, short term store and the long term store. Craik and Lockhart, (1972), proposed an alternative approach to memory known as **Levels of Processing (LOP)**. According to the LOP model, processing of new information is controlled by the central processor and can occur at one or more levels (Parkin, 1995). On the other side Tulving, (1972, 1983, 1987, 1989), put forward a view of the organisation of **Long Term Store(LTS)**. He argued that LTS has three distinct components, Episodic, semantic and procedural memory. Baddeley, (1967, 1976, 1986, 1993, 1994), studied **Working Memory**. He stresses the links between memory and attention, perception, action and emotion. Some other models have also been proposed by other psychologists and educationalists. They have their own individuality and utilities in the perspective of their logical and experimental evidence, but the **predictive model** based on information processing theory, proposed by Johnstone and El-Banna, (1986), at the Centre for Science Education Glasgow University proved its importance and effectiveness in teaching and learning in science education. It is presented here and accepted as significant concern of this study.

3.4.1 PREDICTIVE MODEL

Like other models it has also passed through the steps of modification, improvement, acceptance and implicational processes, in the light of available evidence which appeared during the earlier researches done by, Duncan and Johnstone, (1984), Johnstone and Kellet, (1980), Johnstone and Wham, (1982), El-Banna and Johnstone, (1986). It re-examines the earlier work and adds to them some very effective factors which control the ability to interpret and handle questions, such as the need to reconstruct the meaning for one's self, the limitation on the size of the working space, the noise which swamps the signals and the tendency to be distracted by irrelevant information.

The model represents the flow of information through the memory system and the act of processing that is required to construct meaning. The information processing model makes predictions about how input information is dealt with in the human mind (so that meaningful learning takes place) and what overt performance will be. The following diagram represents the parts of this predictive model for learning science.



The model involves something of all the other models and has been found to be very useful in teaching and learning science. This model focuses on learning and the learner and suggests mechanisms in the learning process.

The three parts of the model which provided a focus for the research are perception, working memory (space) and the long-term memory.

PERCEPTION: It is an active process which uses previous knowledge to interpret the sensory information. The environmental inputs, such as events, observations and instructions first of all come through the perception.

In the multi store model, Atkinson and Shiffin, (1968), perception was proposed as a sensory register (sensory store). It assumed that input information is usually received by sensory stores which hold information in a relatively uninterpreted form for a very short period of time about one to five milliseconds and it is lost at the end of this time. Regarding perception, Johnstone, (1992), declared that "Interest, previous training and culture play a part in the process of perception and it is driven by long term memory, which helps to recognise the familiar and unfamiliar.

Johnstone, Sleet and Vianna, (1994), explain that, in the physical situation of a laboratory there is much more information to be processed than is necessary. For a novice, all of the information is potentially relevant, while for the expert only a limited part of this is important. How is the novice to know the difference between **signal** and **noise** ? The expert knows because the information is selected in the light of what is already held in the long term memory, as theory or as previous experiences. "The precise filtration process is available to the expert but not to novice".

Working Memory: According to the predictive model, the information selected through the perceptive filter is than transferred to the working memory. Johnstone, (1984), states "it is that part of the brain where we hold information, work upon it, organise it, and shape it before storing it in the long term memory for further use". Baddeley and Hitch, (1977), and Johnstone, (1988), agreed that working on a function involves the conversion of new material selected through perception into a comfortable form for storage. The process involves interpreting, comparing, storage preparation and interrelation of new information with material held in the long term memory.

Johnstone, Sleet and Vianna, (1994), explained that this space is treated as a shared space where information from external sources was allowed to interact with information from long term memory, to produce understanding which could be further used or stored. And according to Baddeley, (1986), because the space for holding and operating is limited, it is possible to overload this part of the mind and cause discomfort and confusion. It is unpleasant and exhausting to work at the limit for more than short periods and most people work well below this limit.

Long Term Memory: According to Johnstone, (1992), "Storage is most efficient, from retrieval point of view, if the new is linked to existing material in long term memory to form a branched network which can be accessed in several ways". Johnstone, Sleet and Vianna, (1994), states that long term memory has its link with a perceptive filter system and working memory space. It is a large store where facts are kept, concepts develop and attitudes form.

Most of the hypotheses suggest that information which enters the long term memory does not decay but tends to be kept permanently. It is believed that the storage of a chunk of information in the long term memory takes longer than the retrieval of it, which means that one may retrieve more quickly many chunks from long term memory.

Thus learning is a flow of information from perception to working memory, where it is encoded and then further movement takes place in the form of chunks to store in long term memory and become available for further use.

3.4.2 LEARNING IMPLICATIONS

The relationship between overload of working memory and some learning areas which students perceived to be difficult, has been explored.

Johnstone and El-Banna, (1989), suggested that some interpretation of all problems of learning, teaching and testing can be made by this model, but the suggestion of a mechanism for some problems which do exist and a mechanism by which they might be overcome is certainly possible and obtainable.

Cassels and Johnstone, (1984), indicated that the language in multiple choice questions was influencing the thinking processes necessary to answer the question in that the question posed in a negative form might be beyond the working memory space needed to hold, organise, sequence process and solve it. But a teacher's working memory is already organised, because of his experience and previous organised knowledge.

Due to the large number of variables which influence laboratory instruction, practical work is described as an area of educational difficulty, where the working memory capacity can be easily overload.

Johnstone and Wham, (1982), proposed that the learning in laboratory situations may result in a state of working memory overload because of the large amount of information given at once. The overload also occurs when the learner is incapable of discriminating between the 'noise' and the 'signal' in laboratory instruction. And also overload arises due to the incidental information given by teachers and demonstrators which contributes to an increase 'noise' and become difficult for the students to recognise the 'signal'. Further some laboratory manuals introduce unnecessary amounts of information for the student to cope with.

Johnstone and Letton, (1987), have indicated a perfect example to illustrate the overload of working memory during laboratory work in terms of signal and noise , with reference to the teacher thinking. They showed that, in the laboratory manual, statements are presented in a form with much 'noise' and less 'signal'. There is often no clear distinction between some synonyms used in the lab manual, and hence students are not in a position to distinguish their precise meaning.

Vianna, (1991), while discussing the working memory overload situation, quotes Wham, "What the students perceive to be the requirements of practical work was not what the teachers believe them to be. The content which the teacher is trying to teach is well understood and well organised in his mind. However to the learner, who does not yet have a grasp of the ideas, the position may look very different".

Case, (1977), has suggested the designing of effective instruction with a minimum load on working memory must highlight all stimuli to which the subject must attend, making them salient, either because their physical characteristics makes them stand out from their context, or because they are pointed out verbally by the instructor. The more salient a stimulus, the less working memory is needed to be devoted to the task of extracting.

Pascual-Leone, (1970), recommended, reducing to a bare minimum the number of items of information that require the student's attention. By definition, the smaller the number of items of information with which the student must deal at any time, the smaller the load on working memory.

According to Cavanagh, (1972), teacher should make familiar all cues to which the student must attend and all responses individuals must exhibit. The more familiar a cue, the less working memory is needed for the task of extracting it from the context. Similarly, the more familiar a response, the less working memory is needed for its execution.

Johnstone and Wham, (1982), suggested that the load could be reduced and the signal/noise ratio enhanced by giving a clear statement of the point of the experiment, redesigning experiments and avoiding the teaching of manipulative or interpretative skill at the same time as data is being sought.

Letton, (1987), suggested similar strategies for reducing the noise in the existing laboratories. According to her, one should identify and attend to all areas of possible overload by giving clear instructions on the requirements for the lab report, identifying which instruction matter and which are peripheral, and make this apparent in the material. It could be done by redesigning the experiment with regard to the content, dividing the written material into sections which are easily managed by the students, making the management of the lab efficient and giving a map of the layout of the lab with the location of all equipment and material. Lastly it would help if relevant skills were taught separately from the actual experiment in order that the students should gain confidence in them before having to apply them.

Talbi, (1990), summarised some of the implications as: (a) the traditional presentation of scientific facts and concepts must be re-examined in the light of the demand of a task and the student's capacity, (b) sequencing and organising knowledge, dealing with a bit of information at a time and using familiar language greatly help the students. (c) a student must be helped to develop his own strategies and given the opportunity to practice strategies in terms of breaking down a task in to its parts, dealing with high information loads and separating relevant from irrelevant information. (d) the high demand of a question should be reconsidered since it tests both capacity and strategy.

Johnstone and Al-Naeme, (1991), indicated that, even with a high working memory capacity, a field dependent subject would carry a relatively large amount of 'noise' compared to the low working memory capacity, field independent subject. This amount of "noise' may occupy some of the potential working space, leaving a reduced space for useful processing of the relevant information, the 'signal' of the problem. High working space subjects in a case like this cannot fully utilise their capacity and perform as if their capacity was much reduced. Similar indications also appeared in the studies of Ziane, (1990), and El-Banna, (1987).

3.4.3 CONCLUSION

Having a brief survey of information processing theory and the predictive model of learning, its implications and work done in the area, (science education with special reference to laboratory - practical work at undergraduate level) the researcher has come to the following conclusions.

1. From the information processing framework it is possible to identify the phases of processing that take place from the beginning to the end of a particular bit of learning.
2. The researches into the area of how our memory encodes, stores and retrieves information has provided valuable indicators of what is needed to complete each phase and the conditions required to improve learning.
3. It give an indication of a limited mental space for an individual within which he can deal with the teaching material and the problem solving task.
4. Working memory space is a shared area which permits one to hold (too much to hold means little room for processing) ideas and think about them in terms of encoding, ordering, application of rules and patterns seeking.
5. Knowledge has to be reconstructed as it is transferred from one person to other and also undergoes the process of reconstruction (encodes/chunks) before being stored into the long-term memory within the limits of the individual's mental process of learning.
6. Previous knowledge, experience and acquired skills control the operation of chunking.
7. A Chunk is a piece of knowledge which indicates or helps in remembering what is next or what is before. In other words a chunk is an interelated collection of ideas or concepts which ease the load on working space. Each chunk functions as one unit. A chunk is of any size depending upon the mental organisation of the individual. What

is a chunk for one person may be several chunks for another.

8. Working memory space limits the ability of an individual to carry out learning and problem solving. This means that any task, which requires a number of mental efforts or steps to be solved greater than the learner's mental capacity, will be impossible for him unless he has instructions or strategies to lessen on the burden on his working memory.

9. The predictive model of science education is capable of helping educators to understand more about the learner's limitations and harmonise the helpful ideas derived from the various psychological stances.

10. In the laboratory situation, practical work is described as an area of educational difficulty, where the working memory can be easily overloaded, and influenced due to a large number of variables.

11. The success not only depend on individual's capacity but also on the demand of the task. Instruction can affect task success when the load of a task exceeds the individual's capacity.

12. The load on working memory capacity can be reduced by reducing the 'noise' in existing laboratories.

3.5 COGNITIVE STYLES FIELD DEPENDENCE AND FIELD INDEPENDENCE

3.5.1 COGNITIVE STYLES

Individual differences play an important role in individual learning processes. Witkin, (1977), refers to the individual differences as the cognitive style of learning.

Cognitive style is very closely related to the psychological differences.

Cross, (1976), explained that each individual has his own style for collecting and organising information into beneficial knowledge. He further goes on to say that some students' approach to learning is analytical and systematic, others are intuitive and global. Some students will perform best in groups, while others will do better learning alone. Some students prefer abstract materials and formal discussion, while others prefer concrete material and intuitive argument.

Witkin, (1978), and Kogan, (1976), agree that the cognitive style is the manner in which individuals acquire, store, retrieve and transform information. Kempa, (1979), supports Witkin and Kogan. He states, "cognitive styles are concerned with the processes of mental activities, learning and problem solving."

Witkin, (1981), declared that cognitive styles are ways of moving toward goals rather than goal attainment. He pointed out that cognitive styles are stable over time. This stability extends not only over weeks and months, but over years. And any educational implications of cognitive styles may have long term validity. It does not mean that they are totally unchangeable.

Harmon, (1984), says "The cognitive style is relatively independent of abilities. Aptitude represents a power to do, but cognitive styles refer to the way the power is used. Hadden, (1990), defined cognitive styles as "dimensions of individual differences involving the form of cognitive functioning, with expressions in a wide array of content areas including perceptual, intellectual, social-interpersonal and personality-defence processes".

3.5.2 FIELD DEPENDENCE/FIELD INDEPFNDENCE

The Field-Dependence/Field-Independence dimension in learning styles is related to the ability to overcome an embedding context which appears distinct from the ability to overcome the effect of distracting fields.

Witkin (1974), and Goodenough, (1961), have distinguished between Field Dependent and Field Independent. They explained that an individual is **field-independent,** who can easily break up an organised perceptual field and separate readily an item from its context. And an individual is **field-dependent,** who has insufficient ability to separate an item from its context and readily accepts the dominating field or context.

Goodenough, (1981), emphasises that field-independent subjects have a relatively analytical cognitive style which allows their experiences to be analysed and developed. They have the ability to restructure the fields as required , and have a tendency to adopt a participant role in the learning process which gives an indication of their greater structuring ability. Field-independent individuals learn or remember significantly more than field-dependent under some conditions for example, intrinsic motivation discrimination learning, when non salient cues are relevant. On the other side field-dependent individuals have a relatively global cognitive style which governs their experiences by the organisation of the field. Goodenough indicated that field-dependent people accept the dominant silent attribute of the stimulus and are dominated by the task so that they tend to accept the organisation of the fields as given. Al-Naeme, (1989), stated that "Field-independent subjects seem to be more self-sufficient than field-dependent". Frank, (1984), Kenneth, Nummedal and Collea, (1981), reported a significant correlation between subjects' scores on the field-dependence/field-independence test and performance in proportional reasoning where irrelevant-relevant information was presented, but no significant correlation was found between them when only relevant information was presented. El-Banna, (1987), and then Al-Naeme, (1991), investigated the performance of students in problem solving. They reported the students' ability was dependent on the extent to which they were distracted by irrelevant information. For the group of students with low working memory space, there is a strong relation between student performance and their ability to select relevant information. The relationship is less pronounced for students of medium X-space and there is no relation for students of large X-space. Why ? It is due to the fact that field-dependent people with small working space cannot afford to process irrelevent material because their effective working space is drastically reduced. However field-dependent people with large working space can afford to have some irrelevent material, but have enough space left over to function successfully.

3.5.3 SOME CHARACTERISTICS OF FIELD DEPENDENCE AND FIELD INDEPENDENCE

The literature survey, revealed the following characteristics of field-dependent/field-independent individuals, which has been explored in past researches.

RESTRUCTURING SKILLS: Goodenough and Witkin, (1981), identified two related cognitive restructuring skills that field-independent individuals exhibit more than field dependent, they are (a) breaking up an organised complex field into its basic elements and (b) providing a structure to a field that lacks one, or imposing a different organisation on a field to that which is suggested by its inherent organisation. Frank and Nobel, (1985), show that field-independent individuals are more successful and have greater skills in tasks which involve these cognitive restructuring skills.

Witkin and Goodenough, (1981), suggested that field-dependence/independence could be considered as a way of processing information from a more computed field. Sowder, (1985), states that "the cognitive restructuring aspect of field-dependence/independence is found to be related to problem solving ability". It means that students with a high score on cognitive restructuring tasks are better problem solvers than students scoring low in such tasks.

STABILITY : Witkin, (1977), found that the field-dependence/independence cognitive style is stable with age. "Individual differences in the expressions of articulated functioning in a field are related to expressions in other fields and will not change for months and years". Goodenough, (1976), stated that the individuals who are analytical in one perceptual background tend to be analytical in other perceptual backgrounds and problem solving situations.

GLOBAL AND ANALYTICAL APPROACHES: Witkin, (1974), states that "A tendency towards an analytical or global way of expressing characterises a person's problem solving activities as well as his perception". Further he, (1977), indicated that the learner with an analytical style is more likely to analyse a field when the field is organised. While the learner with a global style is more likely to perceive a field as it is without analysing and structuring it. He found that field-independent students are more likely to give a good performance in problem solving tasks when the solution depends on using an object in an unfamiliar way than are the field-dependent.

Frank and Keen, (1993), indicated that the theory of field dependence/independence is concerned with the performance of individuals for analytical or global information processing. Witkin and Goodenough, (1974), pointed out that the field independent learners show evidence of greater skills in their cognitive analysis and restructuring than field dependants. They further explained that individual differences can be conceived of as an analytical field approach at one extreme and a global field approach at the other. Witkin, (1974), states, "the capacity for analysis and structuring of experiences is the core of field dependence/independence learning style.
Hence it is concluded that field-dependent individuals, approach tasks analytically and the field-dependent individuals approach them in a global way, instead of in parts.

SOCIAL ORIENTATION: Goodenough, (1976), has said that field dependent individuals pay more attention to the significant social aspects of their environment. They tend to acquire significant social cues and ignore others, relying on their relevance to the task at hand. This acquisition may aid performance or sometimes hinder it. On the other hand field independent individuals pay less attention to social cues unless their attention is specifically focused on such cues for some reason.

CONCEPT ATTAINMENT: Research in this area suggest that field independent individuals obtain information more efficiently, rely less on guessing with inadequate information and are more ready to accept the irrelevance of concept attributes than are field dependants.
Goodenough, (1976), stated that field-independent learners are generally better than field-dependent learners in concept attainment tasks. Further he goes on to say that concepts defined in terms of more salient cues has more effect on field-dependent than field independent people in conceptual learning. He argued that field

independent students would learn concepts more rapidly when the salient cue is irrelevant to the definitions of concepts. While field-dependent subjects may demonstrate greater readiness than field-independent when relevant cues and attributes are salient. Field-dependents tend not to ignore the irrelevant attributes and non salient cues in concept definition.

WORKING MEMORY: Pascual-Leone, (1974), Case and Globerson, (1974), and Frank, (1983), pointed out that field-dependent/independent individuals differ in the effective use of their working memory. They agree upon the efficiency of performance in working memory tasks is related to field dependence/independence, and found that field-independents are better in the recall of information stored in the working memory than field-dependents.

INFORMATION PROCESSING: In this area, Davis and Frank, (1979), Davis and Cochran, (1989), Frank and Keene, (1993), found that field-dependent/independent individuals differ not only in how they process information, but also in the effectiveness of their processing.

Harmon, (1984), pointed out that cognitive styles are information processing habits, representing the learners typical mode of perceiving, thinking, problem solving and remembering.

3.5.4 LEARNING IMPLICATIONS

The literature survey revealed that field-independent students score significantly higher than field-dependants in most of the academic areas of science. The greater effectiveness of field-independent students was related to their efficient use of memory. Some relevant investigations and findings concerned with the implication of field-dependence/independence cognitive style of learning is presented here.

Witkin, (1977), suggested that physicists, chemists, mathematicians, engineers and artists are analytical-impersonal people. He claimed that field-independent graduates choose to specialise in such fields as science, mathematics, arts, experimental psychology, engineering and architecture. On the other side field-dependents may choose sociology, humanities, language, clinical psychology and nursing. He found that, in general, grades in science courses correlated positively with the measures of field-dependence/independence. In addition shifts out of science and mathematics were particularly common among field-dependents. He (1976), indicated that field-independent college students were significantly better then field-dependents in science, mathematics, architecture and engineering.

Goodenough, (1961), found that field-independent students have the facility for attending to the essential information in a situation and are not deflected by irrelevant information. They get to the heart of a problem directly, while field dependants have difficulty in separating what is essential from what is irrelevant and easily become confused.

Frank, (1988), studied how the student's performance was affected by particular (note taking) learning. During the lecture, students were required to chose one of three methods, i.e. (a) personal note taking, (b) note taking on a skeletal outline and (c) provisional notes. They found that field independent students in general obtained better results than field dependent when lecture notes were taken by all the students. Davis and Frank, (1979), noted that the greater effectiveness of field-independent students may be related to memory processes employed in concept learning. They further claimed that field-dependents are often less efficient than field independent in their learning strategies. High information load, greater interference potential and less inherent organisation are the factors which contribute to the less efficient memory use of field dependent learners. Frank, (1983), found that field-independent and field-dependent learners differ in the cognitive processes, they employ as well as in the effectiveness of their performance. He concluded that field-dependent students exhibit less efficient memory strategies than field-independents when they encounter a problem. Field-dependent students process information in a rigid way which may be the result of an insufficient response to cues which would facilitate their recollection of the past information. Field-independent students may not be like this, they may recall and encode information without depending, directly upon relevant cues. The relevant cues could be considered as bridges to aid access to the stored information.

Berger, (1977), used the digit span test and two measures of field independence to find out whether there is any correlation between the variables. He found that field-independent students showed a higher performance in working memory tests involving interference than did field-dependents. He concluded that field-independents are superior to field-dependents in the recall of information stored in the short term memory when interference is possible and when the information load is high. Pascual-Leone, (1970), believes that field-independent ability is a developmental characteristic and learners with this ability may have at the same time a high working space, in which case they may be described as high in processors.

El-Banna, (1987), found that there is a direct relationship between students degree of field-dependence and their attainment in examinations. He suggested that field-independent students performed better than field-dependent in all groups of different working space.

Ziane, (1990), indicated that field-dependence/independence was found to play an important role in students success. Field-independent physics students achieved higher scores in solving physics problems than those who were field-dependent in their cognitive style. Al-Naeme, (1991), found that field-dependence/independence cognitive style is very important and plays a vital role in problem solving procedures in chemistry mini projects. He concluded that field independent students are better than field-dependent in conventional chemistry examinations. He suggested that "the field-dependents would find difficulty in separating an item from its content and would accept the context as it is. The field-independent would readily break-up an organised input information and easily separate an item from its context."

Witkin, (1977), concluded that field-independents would be more likely to exhibit a good performance in problem solving situations when the solution depends on using an object in an unfamiliar way. When previously useful cues become irrelevant in the current concept formation task, the performance of field-dependants suffers more than field-independents.

3.5.5 CONCLUSION

1. It can be concluded that cognitive styles are independent of the content of the subject matter. It is the manner in which individuals acquire, store, retrieve and transform information. Or cognitive styles are information processing habits, representing the learners typical mode of perceiving, thinking, problem solving and remembering.

2. Field independent individuals would be better than field dependants in the process

of abstraction.

3. The analytical/non analytical way of thinking may be the best criterion to distinguish the interests of field-independent/dependent individual. Field-independent individuals perceive and process information analytically, while field-dependent individuals do it in a global holistic and passive way.

4. Individuals who tend to be more socially oriented are supposed to be field-dependent and may acquire more social information with greater ease than field independents.

5. Field-dependent and field-independent individuals differ in the cognitive processes, they employ as well as in the effectiveness of their performance.

6. The larger the working memory space of an individual, the more likely he is to be field independent. The smaller the working memory space of the individual, the more likely he is to be the field dependent.

7. Field-dependent students may encounter difficulties in recalling encoded information unless retrieval cues are directly relevant to the way in which the information was encoded.

8. Field-independent students are superior to field-dependants in the recall of information stored, when interference is possible and when the information load is high. Field- independent students would display a greater degree of organisation in free recall task.

9. The performance of field-dependent students would be poorer than field-independent students when the burden of a task on the working memory increases.

10. Sufficient working memory space is needed for use in the process of generating a conceptual response. Field-dependents would exhibit a poor performance in such a situation, since they tend to have low working memory space or use their working space inefficiently.

3.7 SUMMARY

Memory means the mental processes of acquiring and retaining information for later retrieval, and the mental storage systems that enable these processes. Memory refers to three kinds of activities: (a) acquisition of information (b) retention of information (c) retrieval of the information.

There is fairly general agreement that the function of short term memory is to serve as a working memory, which is a system that allows several pieces of information to be held in mind at the same time and interrelated.

The predictive model of learning science provides a focus to cover more or less all the mental activities which occur during learning processes and cited in all the other models. The working memory is used as a shared space where information from external sources is allowed to interact with information from long-term memory to produce understanding which could be further used or stored. And long-term memory is a large store where facts are kept, concepts develop and possibly attitude form. This interacts with both the working memory and the perception filter.

Cognition is the collection of mental processes and activities used in perceiving, remembering, thinking and understanding as well as the act of using these processes.

Cognitive styles are concerned with the form rather then content of cognitive activities. they refer to the individual differences, how to perceive, think, solve problems and learn to relate the others.

Field-dependence/field-independence are cognitive styles of learning. Cognitive styles tend to be stable over time. The ability to disembed a hidden figure from a distracting background is indicative of cognitive style field-independence, and by contrast to this is indicative to cognitive style field-dependent. Field-independent and field-dependent individuals tend to favour different learning approaches. The approaches favoured by the one kind of individual do not necessarily make for better achievement than the approach favoured by the other kind.

Field-dependent individuals may have low working memory space. They find some difficulty in separating signal from noise and are less efficient than field independent individuals. According to the predictive model of learning science, if some relevant information is provided in advance and stored, it would be accessed from the long-term memory which would improve the process of separating signal from noise.

CHAPTER FOUR

GOALS, AIMS AND OBJECTIVES

4.1 INTRODUCTION

"It is very hard to think about what you are doing in laboratory teaching", Ogborn, (1977). How shall I think about what practical work is for, and how might what I want to happen be made to happen? This is the question around which this chapter revolves.

Gagne', Ausubel, Information Processing theories and Predictive Model of Learning Science all stress the importance of previous knowledge to future learning. How could this be applied to laboratory work to turn it from blind recipe following to an intelligent cognitive experience. Could the students' mind be "made ready" so that they become more like experts, able to separate noise from signal, to recognise the purpose of what they were doing and to take some active part in making the experiment "their own" ? This led to the idea of a pre-lab to alert the student to the crucial (signal) features of the experiment.

Understanding built from the Information Processing Model of Learning motivates me to start with the goals, aims and objectives of science education, already set out by scholars, educators and physicists. The last sections of the chapter sets out the overall aims and objectives of this piece of research work.

4.2 AIMS AND OBJECTIVES OF SCIENCE EDUCATION

Science education, like every discipline, has certain aims and objectives. Thurber (1964), describing the historical development of objectives in science education, gave long range objectives. According to him, the aims of science education are to provide:

(i) a basic knowledge of the nature of the scientific enterprise.

(ii) an increase in mathematical, observational and experimental skills.

(iii) understanding of the concepts and theories which describe and unify the field of science.

The same author has also reproduced the objectives of science education developed by the National Science Teachers Association. They are to:

(i) acquire a working concept of the relation between science and society, science and individual, science and technology.

(ii) have varied and pleasant experiences in activities related to science and know something of the development of science and of the people who contributed towards it.

(iv) have adequate understanding of science, as well as some command of more important functional knowledge in science.

Richardson, (1957), has also given the objectives of science education in the instructional form. These objectives are to:

(i) develop the ability to think critically, to use the methods of science effectively.

(ii) acquire the principles, concepts, facts, and appreciations through which they can better understand and appreciate the nature of the earth, its inhabitants and the universe.

(iii) use wisely and effectively the natural sources of the earth as well as products of science and technology.

(iv) understand the social function of science and think and act in relation to the implications of science and technology.

(v) acquire information, understanding and appreciations that will contribute to their educational and vocational guidance.

According to Bloom, et al. (1971), "The principal purpose of science education is to develop in the students scientific literacy". The Asian Centre of Educational Innovation For Development (ACEID), news letter (1979), in a special issue on science education has given the objectives of science education as: "Development of the ability and attitude of enquiry into nature through observation and experimentation for deepening and understanding of basic science concepts and fostering a scientific view of nature".

The following aims are summarised here to give the reader a picture of what the students did at school. In an ideal world every student would have attained every goal set out for every aim, but in practice, many of these aims are only partially fulfilled and have to be revisited and amplified in tertiary education.

Reviewing science education, Prest, (1976), suggested a two stage framework identifying the following aims of science education.

I. Primary stage (5-11yrs:)

(i) Development of the use of the scientific skills.

(ii) A beginning of an understanding of how the scientist works testing statements against experiment.

(iii) Acquisition of scientific facts as they arise from the child's experiences and interest.

(iv) A beginning of understanding of the simpler scientific concepts.

II. Secondary stage (11-16yrs:)

(i) Further development of the scientific skills.

(ii) Increasing experience of using scientific methods.

(iii) Basic scientific facts and concepts arising from their use as illustrative material in (i) and (ii).

(iv) Development of structures relating concepts.

(v) Social and economic implications of the applications of science.

(vi) Science as an activity of the community at large.

Prest further says the aims of science education are the development of 'simpler' or 'basic skills' at the primary level and 'integral skills' at the secondary level. "The basic skills at the primary level are: observing, communicating, classifying, predicting, inferring, measuring, using numbers, using space time relationships. Integral skills are: interpreting data, formulating hypotheses, controlling variables, defining operationally, experimenting".

Heaney, in the Association For Science Education, (1981), has developed the following aims of science education:

(i). The acquisition of a knowledge and understanding of a range of scientific concepts, generalisations, principles and results through the systematic study and experience of aspects of the body of knowledge called science.

(ii). The acquisition of a range of cognitive and psychomotor skills and processes as a result of direct involvement in scientific activities and processes in the laboratory and the field.

(iii). The utilisation of scientific knowledge and processes in the pursuit of further knowledge and deeper understanding, and the development of an ability to function autonomously in an area of science studies to solve practical problems and to communicate that experience to others.

(iv). The attainment of a perspective or a way of looking at the world together with some understanding of how it complements and contrasts with other perspectives or ways of organising knowledge and inquiry.

(v). The attainment of basic understanding of the nature of advance technological societies, the interaction between science and society, and the contribution science makes to our cultural heritage.

(vi). The realisation that scientific knowledge and experience is of some value in the process of establishing a sense of personal and social identity".

The Association has further stated that, "this is the frame work through which the specific aims and objectives of different courses and stages of educational process can be determined, so all schools should have a strategy that enables aspects of the aims of science education to be achieved through appropriate work in science and other subject areas".

4.3 GOALS, AIMS AND OBJECTIVES, PHYSICS EDUCATION

"An aim or goal is not the same as a learning objective", Meester and Maskill, (1995). An aim is a broad and general statement about the teaching intention of an experiment or a course. Objectives are far more precise and describe what students are able to do after carrying out an experiment or finishing the course. The general aim of an experiment can be (re)defined into more specific, behavioural objectives. Aims and objectives are distinct parts of the overall communication of the teaching learning enterprise.

According to Woolnough (1983), Johnstone and Letton (1988), for practical work to be effective and efficient, the aims have to be defined in advance and the most suitable instructional method has to be chosen. A consequence of this procedure may be the decoupling of lectures and practical work. Although theory and practical are interdependent, practical work need not to subservient to lectures in any illustrative sense or for the verification of theoretical concepts. It has goals of its own which ought to be consistent with the general goals of the science degree programme. Practical work is a means to reach these goals and should never be an end in itself.

Meester and Maskill, (1995), suggested that a list of aims and objectives can be very useful and valuable and is actually necessary for (a) making choice about what one would like to achieve with practical work and about the most appropriate instructional methods; (b) evaluating the practical work with respect to quality and effectiveness of the learning process; (c) clarity to the student; and (d) providing an organising element, not only for the structure of a course but also for the learning process.

Housten, (1970), classified the broad aims of physics in two levels i.e. a secondary school course for pupils who study physics throughout their secondary school career, and undergraduate courses leading to an honours degree in physics. The undergraduate course objectives are presented below.

"**HONOURS PHYSICS COURSE:** According to Housten, (1970)), It is the intention of such a course to develop in the student the abilities which are considered necessary if the student is later to become a competent professional physicist working in some special field of research or development. The broad aims of the course could be stated as; (a) To provide initiation into an unequivocal tradition of thought, so that the student becomes aware of current consensus viewpoints; e.g. he must know of the wave/particle duality of light and why it is part of the accepted body of knowledge. He will be unable to detect anomalies in the accepted viewpoint unless he knows what that viewpoint is. (b) To develop in the student an ability to operate sophisticated equipment in a laboratory and to use appropriate measuring techniques. Unless he knows how to design an experiment he will be unable later on in his own research work to design experiments which will bring theory and observation into closer agreement and thereby remove anomalies in our understanding of the physical world.

While giving an account of physics curricula for courses leading to a first degree with physics as the main subject, Black, (1976), set out the following goals, aims and objectives for tertiary level.

The goals of the curriculum ought to relate to employment opportunities but should not necessarily be matched in a narrow way to the needs of particular occupations.

A second possible goal for a degree curriculum is that of providing a general education through physics. This has the implication for employment that both graduates and prospective employers consider physicists to be well equipped for a wide range of careers.

The third goal is one of training physicists who are prepared to use their physics in a wide range of practical applications. And is relevant everywhere but has additional force in the developing countries.

Dr. A S Watt, Head of the physics-II laboratory during the session 1994-95, identified the following aims of physics education.

-To understand the nature of the universe.

-To identify and study the fundamental particles from which the universe is built, and to discover and understand the forces between them.

-To understand how certain groups of these fundamental particles can behave collectively as if they themselves were forming ever more complicated structures.

-To understand the properties of solids, liquids and gases, and manufacture new materials with specialised properties.

Nedelsky, (1965), proposed a set of objectives under the three headings, 'knowledge', 'understanding', and 'ability to learn', which he uses for learning science in general and physics in particular. The three headings form some kind of hierarchy of increasing demand and scope. The list of objectives looks like this:

Laboratory Knowledge:

(I) Knowledge of apparatus and material.

(ii) Knowledge of laboratory procedures.

(iii) Knowledge of relations between data and generalisation from data.

Laboratory Understanding:

(i) Understanding of processes of measurement.

- Working of apparatus.
- Methods of measurement.

(ii) Understanding of experiment.

- Experimental design.
- Performing an experiment.
- Interpretation of data.

Ability to learn from experiment or observation.

(i) Ability to pursue experiment or observations.

(ii) Possession of laboratory skills.

(iii) Disciplined thinking.

Woolnough (1983), claimed three fundamental aims for practical work and linked each aim to a specific instructional strategy. The first aim, developing practical skills, can be best achieved through practical exercises of a structured and convergent type. The second, learning to work as a problem-solving scientist, can be best developed through practical investigations or projects of an open-ended or divergent type. Finally getting a feel for phenomena can be learned through appropriately devised and practical experience.

According to Kirschne, (1991), practical work is best suited to the teaching of the syntactical structure of knowledge. He defined three motives for practical work in a slightly different way from Woolnough. Specific skills, where practice and feed back are important, can best be developed in simulations. An academic approach to work can best be achieved by experimental seminars, in which discussion, comparison and modelling play an important role. For experiencing real phenomena, laboratory work is most appropriate. Although these attempts to couple aims or motives with teaching methods differ slightly from each other, they have in common the importance of designing specific instructional strategies to achieve practical aims. Designing practical experiment with just one aim in mind may reduce the overload, Johnstone and Wham, (1992), & Friedler and Tamir, (1986).

This survey of science and physics education objectives, at different levels, is carried out with the intention of making a bridge between the objectives already set out and the objectives of this research for physics II lab. To have a further insight some record of the objectives for physics-II, being used in UK is shown in **Appendix-A**.

The objectives of physics-II, set out by the University of Glasgow, Department of Physics, where the researcher has carried out this piece of research work, is reproduced below.

4.3.1 G.U, AIMS AND OBJECTIVES, PHYSICS - II

Glasgow University, Department of Physics and Astronomy, (1995), have adopted the following aims and objectives for Physics-II.

Course Aims:

This course presents physics to those who intend to continue to Honours in the subject in third and fourth year, as well as to others who do not wish to continue with physics beyond second year. The course aims to inspire and to educate, to train and to inform. Physics is a general skill transferable to other Physical sciences, Engineering, Biological sciences, Medicine and many aspects of industry.

COURSE OBJECTIVES:

On completion of this course you (student) should:

-have an improved and deeper understanding of the basic laws of physics than at the end of first year, and know when and how to apply them in a wider range of contents;

-know the experimental basis of these laws, and appreciate how they fit together;

-solve problems by applying these laws;

-be able to apply mathematics, particularly to describe continuous change with time and continuous distributions of charge and matter;

-know the precise definitions of many technical terms used in physics;

-be familiar with experimental equipment;

-know how to make measurements and assess their accuracy;

-be able to keep laboratory records, to write reports and to use the library to research a subject of your choice.

4.3.2 OBJECTIVES OF LAB WORK PHYSICS - II

Glasgow University Department of Physics and Astronomy Lab Manual, (1995-96), lists the following aims and objectives for the Physics-II laboratory course:

(a) To illustrate and demonstrate the physical principles dealt with in the accompanying lectures course.

(b) To give you (student) experience of the different equipment and techniques used in the measurement of various physical quantities.

(c) To give you practice in the recording and analysis of experimental data .

(d) To help you to write a clear and concise account of an experiment you have performed.

(e) To teach you transferable skills.

The transferable skills identified in the laboratory are report writing and word processing, data analysis and use of spread sheets, oral presentation of results, group working, punctuality, good time keeping and timely completion of assignments. The students experience in the lab presents apparatus to practice these activites which are generally useful in later life.

4.4 TWO DOMAIN AIMS AND OBJECTIVES OF PHYSICS AT UNDERGRADUATE LEVEL

Having surveyed, briefly, theories of child development, taxonomy of educational objectives and the Physics education objectives, already set out, the researcher is led to the following aims and objectives for under graduate physics teaching, within the limit of two domains i.e. the cognitive domain and the affective domain.

4.4.1 AIMS AND OBJECTIVES - COGNITIVE DOMAIN

Under this domain aims and objectives are:

1. To present physics to the students as a stimulating subject, intellectually satisfying and significantly related to their experiences of life.

2. To develop in the students an understanding of the structure of physics and an awareness of the fact that physics is an expanding field.

3. To familiarise the students with the fundamental principles, theories, and concepts of physics in modern terms and the scope of physics.

4. To develop in the students skills of making careful observations collecting data and calculating the results of their experiments.

5. To develop an ability in the students to interpret the results of their experiments and to understand the implications of these results.

6. To develop skills of setting up appropriate apparatus for experiments and to improve where necessary.

7. To prepare scientifically educated individuals as useful member of society.

4.4.2 AIMS AND OBJECTIVES - AFFECTIVE DOMAIN

The aims and objectives under this domain are:

1. To inculcate scientific attitudes amongst the students and to develop an aptitude in scientific pursuits and an interest in scientific and technical vocations.

2. To inculcate in the students the habit of scientific and rational thinking and an attitude to search for order in the diverse phenomena of nature.

3. To help the students feel that the advancement of physics and its extended applications are essential for the health and growth of the national economy and to appreciate that physics is a major part of modern culture.

4.5 AIMS AND OBJECTIVES OF THIS RESEARCH

The general aims of this research is to study the way in which the Department of Physics delivers the physics-II laboratory course, and to use the Information Processing Model to try to improve the delivery by reducing information overload in the students working memory and improving the signal to noise ratio. This was done to prepare the long term memory and activate the perceptual filter. Accordingly we introduced pre-lab sheets to explain the unfamiliar aspects of the experiment which would be described on paper before the student was confronted by the equipment, and post lab sheets to help with meaningful learning and storage by providing opportunities to use the new learning and reinforce the student knowledge to test the effectiveness of the pre-lab sheets.

4.5.1 RESEARCH - OBJECTIVES

The research objectives are as follows:

KNOWLEDGE

-To explore the effectiveness of pre and post lab studies in the physics II lab.

-To find out if field-dependent and field-independent student have a different attitudes to experimental work, and to rationalised these differences.

-To correlate scores in field-dependent/field-independent subjects with scores in different aspects of academic work.

ATTITUDE & SKILLS

-To enable the student to use their working memory to its full while doing the experiment by

(a) Presenting in the pre-lab sheet as much new material as possible so that this material can be accessed from their long term memory when they are actually doing the experiment.

(b) Increasing the students ability to discriminate signal from noise while working in the physics II lab.

4.5.2 SAMPLE - AIMS AND OBJECTIVES

Glasgow University, Department of Physics and Astronomy, Physics-II Laboratory students are the sample of this research study, during the sessions of 1994-95 and 1995-96. The general aims and objectives have been considered in section 4.3.2, and following more specific objectives can now be added.

As a result of following the course, lab manual, pre and post lab sheets, and time to time instructions in the lab, student should acquire:

KNOWLEDGE

-Realisation that knowledge of Physics and experimentation is of some value in the process of establishing a sense of personal and social identity.

-To build adequate understanding of broad generalisation and conceptualisation of physics, as well as some command of more important functional knowledge in physics II lab work.

-To give understanding of transferable skill.

-To develop an ability to observe critically and to report facts accurately and understandingly.

SKILLS

-An increase in the measurement, experimental and observational skill.

-Development of the use of scientific skills.

-To give practice in recording and analysing of the experimental data.

ATTITUDE

-To develop the habit of preparation before coming to the lab.

-To develop the ability to think critically, to use the methods, principles and laws of physics effectively.

-Develop the habit of acquiring information, understanding and appreciation that will contribute to their educational and vocational guidance.

-To enable the students to react rationally and with scientific attitude to the changing environment.

Four of the five experiments in the physics-II lab, were considered suitable for the purpose of this research. The fifth experiment 'Computational Physics' was unsuitable for this research, as it was purely computer programming with no actual experimental content. The objectives of the four suitable experiments are as follows.

4.5.2.1 X-RAYS - OBJECTIVES

After Completion Of This Experiment The Student Should Be Able:

KNOWLEDGE

-To understand the properties of x-rays.

-To understand the uses of x-rays.

-To explain the planes of reflection in a crystal.

-To know the value of inter ionic (atomic) distance in a crystal of LiF.

-To explain how an x-ray spectrometer works.

-To understand the meaning of spectrum.

-To understand the Bragg conditions.

-To understand the difference between the angle of incidence in optics and x-ray diffraction.

-To understand the atomic processes giving rise to x-rays.

-To explain the difference between line and continuous spectra.

-To understand the principle of operation of a Geiger counter.

-To understand how the intensity of an x-ray beam decreases with distance travelled through a partial absorber.

-To understand how absorption of x-rays varies with the atomic number of the absorber.

SKILLS

-To read the rate meter.

-To obtain a spectrum of the x-rays emitted by copper.

-To identify discrete lines in an x-ray spectrum.

-To measure the wave length of copper K_α K_β lines.

-To measure the distance between planes of ions in crystals of KCl and NaCl.

-To use the spectrometer properly.

-To set the operating voltage of the Geiger counter .

-To make a fine adjustment of a thin end Geiger counter.

-To set and reset the time switch.

-To operate the safety interlock which guards against accidental exposure to x-rays.

ATTITUDE

-To practice safety procedure when dealing with ionising radiation and other hazards.

-To develop the habit of discussing the experiment with other students.

4.5.2.2 LASER - OBJECTIVES

After Completion Of This Experiment The Student Should Be Able:

KNOWLEDGE

-To understand the formation and intensity distribution of the diffraction patterns from a single slit.

-To understand quantitatively how the diffraction pattern changes when the wavelength of light, distance from slit to screen or slit width is changed.

-To understand that the intensity pattern from two identical slits consists of a rapidly varying interference pattern from the two slits modulated by a slowly varying diffraction pattern from one slit.

-To understand how two dimensional diffraction patterns arise.

SKILLS

-To measure the wavelength of light by analysing a diffraction pattern.

-To compare the diffraction patterns from several slits with those calculated by computer.

-To use a travelling microscope to measure the size of a small object.

-To use a vernier scale.

ATTITUDE

-To develop the habit of comparing experimental results with computer calculation.

-To make a rough estimate of a final result from first measurements to check the correctness of their procedures.

-To estimate uncertainties in raw measurements and calculate errors in their final results.

4.5.2.3 RESONANCE - OBJECTIVES

After Completion Of This Experiment The Student Should Be Able :

KNOWLEDGE

-To understand the meaning of resonance.

-To understand how the amplitude of oscillation of a resonating system depends on the frequency of the external driving force when that frequency is near, much less than or much greater than the natural frequency of the system.

-To understand how the relative phase of the oscillation varies with frequency when near, much less than or greater than the natural frequency.

-To understand how damping affects the natural frequency of oscillation and the amplitude near resonance and at low and high frequencies.

-To understand what is meant by the Q of a resonating system.

-To understand why integrating amplifiers are required to detect the displacement of the vibrating bar.

-To understand why the vibrator should be driven by the low impedance output of the oscillator.

-To distinguish between transient and steady state behaviour.

SKILLS

-To make the electrical connections as shown in the circuit diagram in the manual.

-To compare and contrast mechanical and electrical resonating systems and to identify analogies between mechanical and electrical quantities.

-To adjust the output voltage of the oscillator to give an appropriate amplitude of oscillation of the vibrating bar.

-TO USE THE OSCILLOSCOPE :

-To switch it on and locate the two beams.

-To adjust the intensity and focusing of the beams.

-To adjust the time base, to select the correct triggering input and adjust the triggering to give a stationary display of the oscillation on the screen.

-To measure the phase difference between the two signals using the grid and time base settings.

-To measure from a graph of variation with frequency of the voltage across the capacitor in a series LCR circuit the following:

-The amplitude of the driving voltage.

-The maximum voltage.

-The angular frequency at resonance.

-The angular frequency for a phase shift 90^{o}.

-To draw a suitable linear graph to test simple non-linear relationship between variables.

ATTITUDES

-To develop the habit of observation of the principle learned in the experiment in every day life.

-To transfer the knowledge acquired in the experiment to an understanding of other resonating systems.

-To be willing to communicate to a lay person the principles of resonance.

4.5.2.4 MICHELSON INTERFEROMETER - OBJECTIVES

After Completing This Experiment The Student Should Be Able:

KNOWLEDGE

-To give an account of the principles of the operation of the Michelson interferometer equipment which uses division of amplitude to produce interference fringes.

-Distinguish between interference by "division of amplitude and division of the wave front".

-To explain, what is meant by the terms monochromatic light, white light, interference fringes and optical path length.

-To explain the formation of circular fringes, parallel fringes, and white light fringes.

-To explain the operation of the reduction arm and how it can be used to control very fine movements.

-To explain how two closely spaced wave lengths of equal intensity can produce distinct fringe patterns or indistinct fringe patterns with ill-defined positions.

-To explain why the position of zero path difference corresponds accurately to a position of distinct fringes.

-To explain the relationship between the density and refractive index of a gas.

SKILLS

Manipulative:

-To make delicate adjustments of mirrors to obtain fringes with monochromatic light.

-To adjust the path length to obtain white light fringes.

-To adjust the air valve to change the air pressure in the gas cell.

-To recognise interference fringes when they see them and to differentiate at a glance between large and small fringes.

Measurement:

-To read a micrometer.

-To read a pressure gauge.

ATTITUDE

-To be willing to discuss the operation of the apparatus with other students.

-To treat delicate equipment with care.

-To make a rough estimate of a final result from first measurements to check the correctness of their procedures.

-To estimate uncertainties in raw measurements and calculate errors in their final results.

The statements are not intended to imply that the student starts the experiment as a complete novice and after the experiment has become an expert in the field. The desired outcome is more modest. For example, if we take the very last objective all students can make an attempt at placing limits on the accuracy of measurement, but this skill is sharpened by the experience and practice of doing the Michelson experiment. The student will continue to develop this skill by doing other experiments in the future.

4.6 SUMMARY

Education is a human enterprise, and a discussion which concentrates mainly on, goals, aims and objectives of science and physics education is incomplete. More explicitly, there is a part of learning to be a physicist which cannot be learned from books, but only from working with equipment and with other physicists, and it is that part which laboratory is well fitted to serve.

In this research, laboratory teaching is studied against the following criteria.

-In the perspective of aims and objectives proposed by the educationists, physicists, scholars, Universities and Departments, and keeping in view the information processing model of learning, the objectives have been developed for this research study. Mainly to explore the effects that of prep-lab on the execution of the experiments and the abstraction of usable learning

-Selection of four experiments and development of the objectives, for the experiments, is based on sample achievement under the headings of knowledge, skills and attitude.

-The researcher tried to analyse four experiments in the physics-II lab in order to provide the student with a course of study before coming to the lab.

-This study intended to improve the signal to noise ratios while the student is actually in the lab doing the experiment.

CHAPTER FIVE

HYPOTHESES AND METHODOLOGY

5.1 INTRODUCTION

The theoretical basis and hypothetical background is derived from Information Processing Theory, in the psychological perspective that is Gagne's **learning hierarchies** (pre-knowledge) and Ausubel theory of **meaningful learning** (pre and post-knowledge).

At this point in the thesis, all the different aspects of psychological theories of learning, the aims of science education, and of the physics experiments available, have been discussed. It is now appropriate to consider the educational experiments, their outcomes and the hypotheses.

This work was carried out for a period of more than two years in the physics-II laboratory of Glasgow University, and consists of two phases, that is the Attitude, as phase-I and Cognition, as phase-II. The detail of the period and that of the tools administered to the sample along with size and time table is presented here.

To explore laboratory learning, particular emphasis was laid on the way the student reacts to the practical. Pre-labs were used in phase-I (session 1994-95) followed by measurement of attitude changes, and in phase-II (session 1995-96), pre-labs were used followed by the post-labs to measure the cognition gain. This was further checked to see if the learning styles played any part.

Many methods are used in cognitive psychology to test the field-dependence/field-independence cognitive style of students. The researcher has applied some methods that have been developed and modified by other researchers.

In this chapter attention will be paid to the hypotheses, the methodology and the procedure adopted in this study to measure the student attitudes and cognitive styles.

5.2 HYPOTHESES

RATIONAL-I

Johnstone, Sleet and Vianna, (1994), pointed out that "much of the student behaviour in laboratories is that of recipe following. They gain hand skills but it is all too possible to follow mindlessly the instructions in a manual".

Moreira, (1980), found that in many cases, students perform an experiment without clear ideas about what they are doing or what lies behind the experiment. Many of them are not able to identify the physical concepts or basic phenomena. In which case if students don't know either the physical concepts or phenomena involved when they are dealing with the experiment, then the experimental instructions could hardly contribute towards their understanding of the experiment.

According to Johnstone, (1980), a common factor of working memory overload seemed to appear in all areas of science which students perceived to be difficult. Such load may be found in the laboratory in terms of **noise** and **signal**, language in terms of familiarity and confusion, material in terms of density of information and the subject itself in terms of its nature.

Ziane, (1990), notes that in laboratory work there are many factors which can cause student difficulty and even lack of success. This can be so if there are many steps in the practical process, with a resulting heavy load of information. This causes high demand and as a consequence of this overload, the students may not understand the task in hand due to lack of processing.

Al-Naeme, (1991), suggested that students have difficulty in separating relevant information from 'noise'. For the novice, all the information seems to be important. Until they have a good grasp on the material and its concepts they cannot discriminate between the vital things to learn and the peripheral things. In the process of teaching, a lot of peripheral material may be given by the teacher, often unconsciously.

Vianna, (1991), concluded that "there is a possibility of overloading students' working memory leading them to follow the experimental procedures with little or no understanding of what they are doing".

A number of other investigations have suggested that the common factor which seemed to appear in practical courses of physics which students perceived as difficult is that of working memory overload. During the practical, students were unable to distinguish the signal and noise, because they lacked experience to be able to chunk or group the information flowing into the working memory.

In the particular case of the physics-II laboratory there is much more information to be processed than necessary. The predictive model of learning science suggest that 'the precise filtration process is available to the expert, but not to the novice'. Therefore to improve the learning in the laboratory, something would have to be done to give the student access to some of his long-term memory stock or to supply new material to long term memory. This led us to introduce the pre-lab, which is explained in section 5.3.2.

According to the model 'The information to be held and the processing have to share the same limited space (working memory)'. To provide memory space to carry out a process the student should have only relevant information in advance from the manual, so at the time of the practical, they can organise and sequence the required procedure in such a way as to produce meaningful learning.

Keeping in view this perspective, the researcher intended to concentrate on three principal and interlinked strategies to improve the physics-II laboratory teaching.

(a) Use the pre-lab (described in section 5.3.2) to involve students in a more expert role.

(b) Revise the lab manual (described in section 5.3.1) to reduce the noise and so reduce the overload .

(c) Devise the post-lab (described in section 5.6.3) to cause the students to revisit existing knowledge and concepts with a view to making new and richer interconnections in long term memory.

Thus the present study is intended to find out the effectiveness of the method of reducing overload on working memory and to link this idea with the cognitive style field-dependent/field-independent. This led the researcher to raise the following hypotheses.

1. The Pre-lab can foster in students a more positive attitude to physics-II practical work, because of increased confidence and increased participation.

2. The Pre-lab can help to improve the student's understanding of physics-II practical. Because the longterm memory is activated to receive the new material in a meaningful way.

RATIONAL-II

Witkin, (1974), and (1978), has found that in psychology, a cognitive style is recognised called field-dependence at one end and field-independence at the other end. Field-dependent people are particularly prone to be influenced by incidental information and have difficulty in separating 'noise' from 'signal' in any situation. Field-independent people are better at getting to the nub of a situation and ignoring the incidentals.

Johnstone, (1988), says that some subjects have difficulty in separating relevant information or 'signal' from irrelevant information or 'noise'. For the first time learners (novices) all the information presented to them will seem to be important. Until they have good grasp on the material and its concepts they cannot discriminate between the vital things to learn and the peripheral things. In the process of teaching, a lot of peripheral material is given by the teachers, often unconsciously.

According to El-Banna, (1987), field-dependent students will not be capable of choosing relevant from irrelevant information (signal from noise). Since both the 'signal' and 'noise' have to share the students' limited working memory space, the field-dependent students, will not be able to analyse the question's data in a complex situation, nor to synthesise simultaneously the thought steps required to solve the question.

The results of studies reported by Kempa, (1983), tend to support the importance of the field-dependence/independence cognitive style as a factor influencing students' learning.

Relevant to the students' working memory space it is very important to test the influence of this cognitive style on the students' performance at undergraduate level particularly in the physics-II laboratory course. It is to be expected that an extreme field-independent student would benefit little from pre-lab sheets as he is adept at separating 'signal' from 'noise'. At the other end of the spectrum, a field-dependent student should derive a great deal of benefit from the pre-labs. Real students fall between the two extremes but there should be some correlation between field-dependent/field-independent and attitude and cognitive changes. This perspective made the researcher raise the following additional hypotheses.

3. Overall performance of field-independent students should be better than that field-dependent student.

4. Field-independent students with pre-lab will perform better in the experiment than field-dependent with pre-lab.

5. Field-independent students without pre-lab will perform better than field-dependents without pre-lab.

6. Field-dependent students with pre-lab will perform better than field-independents without pre-lab.

To test the hypotheses, an experimental design, which was extended over a period of two years, was developed. It consisted of two phases, an **attitude phase** to measure the students' attitude and a **cognition phase** to measure the students' understanding. These two phases are described in more detail on the following pages.

5.3 PHASE-I (1994-95) THE ATTITUDE

Phase-I focuses mainly on the student's attitude to the changes made in the physics-II laboratory procedure and extended over the academic session 1994-95, which covers two terms. During this phase the physics-II lab-manual, the introduction of pre-lab and to a lesser extent post-labs, and students' attitudes were under scrutiny as described below.

5.3.1 LAB MANUAL

Traditionally in the Physics-II laboratory, students are asked to do the experiments following the lab-manual's procedures and they get help as well from demonstrators and staff when necessary.

Johnstone and Cassels, (1978), found that the words which are normal in English usage give more trouble than those which have a specific meaning in science. For example, the word "power" means strength in every day English, while its strict scientific use means rate of doing work; and so on.

The literature contains many reports of information processing research which has direct implications for the design of instructional written materials. These researches, besides helping us to find out how the information is processed in our cognitive system, also indicate what ought to be avoided, or what could be used to improve the process of encoding, decoding and retrieval. Hence it is essential to provide good written instructions which give information not only about the experimental procedures, but also about the basic organisation of the laboratory and the laboratory techniques involved in the practical.

At the beginning of this study it was decided to take all possible measures to limit the information input to working memory by cutting out extraneous and potentially confusing asides in the written instructions, to make the manual as direct and clear as possible within the limits allowed by the Department of Physics and Astronomy. This is just common sense, but it was remarkable how much extraneous 'noise' was found in the manuals that were thought to be models of clarity. Another factor in limiting the external information flow was linked to the arguments above about perception. If the student can separate **signal** from **noise** and if they had a personal, conscious input to the experimental design, they would attend to the information input in a selective way and reduce the potential for working memory overload.

The relevant part of the lab manual, specially the experiments which are of concern to this study is presented in the **Appendix-B.**

5.3.2 PRE-LAB

The literature survey revealed several kinds of pre-lab work, for example, (a) reading the laboratory manual before starting the experimental work, (b) solving theoretical problems related to the experiment before coming to the lab course, (c) doing computer simulations of experiments, (d) listening to a short talk about the most important points of experiment in the first half hour of the lab session, (e) understanding audio-visual preparation and so on. Pickering, (1979), adopted a pre-lab preparation in which the students were not allowed to bring the manual into the laboratory. This was supposed to allow the student to develop their own experimental procedure and essentially write their own lab manual.

The importance of previous knowledge in the learning process has been stressed by educators and psychologists and it has also been the subject to several investigations. Students' preparation before starting practical work should increase the chances of their understanding what they are doing in the lab. This is intended to avoid a 'cook book' or 'recipe following' scenario. According to the predictive model of learning science, it is already explained that, for a novice, all of the information in a laboratory is potentially important and relevant, while for the expert only a limited part of this is important, because the precise filtration process is available to the expert, but not to the novice.

Keeping this in view, pre-lab sheets were prepared for the experiments of the physics-II laboratory course selected for this study. An attempt was made to list all the possible relevant questions to the particular experiment which may arise in the mind of a novice when he enters the lab or starts the practical. These questions can be 'noise' and if the answers are already known then the load on working memory can be reduced.

Hence according to the nature of the experiment and in the perspective of our psychological model, pre-lab sheets were developed for the selected physics-II experiments. These pre-labs were constructed under the headings and responses such as, (a) what does it do ? (b) how does it works ? (c) what will it measure? (d) what should I know before I begin ? (e) what do I do ? (f)..... and so on.

Some other supplementary but necessary information was also provided to the students, according to the demands of the experiment. For example the pre-lab sheet for the Michelson Interoferometer experiment was extended to include some relevant additional instructions. Pictures of a micrometer screw gauge were also presented on the pre-lab sheet. Many students had never seen a micrometer screw gauge before and obviously they did not know how to use it.

A mini computer program was also prepared for this particular experiment, so the student could see a working demonstration of a micrometer screw gauge on the computer screen, well before the start of the experiment.

The aim of the pre-labs was to prepare the students to take an intelligent interest in the experiment by knowing where they were going, why they were going there and how they were going to get there. In this way potential noise would be reduced.

One specimen pre-lab along with a post-lab, used during phase-I is presented at the end of this section and a complete set of pre-lab sheets for each experiment is presented in **Appendix-C.**

POST-LAB: A small but comprehensive post-lab was introduced at the end of each experiment. The purpose of introducing this post-lab during phase-I was two-fold. The students could review their work and learning, and the researcher could observe the students' reactions. In this phase of the research it was not compulsory for the students to do the post-lab after completion of each experiment. The questions developed in the post-labs were not superficial, but less attention was given to the post-labs and their results during the first phase. This was because phase-I was planned to focus the student's attitude towards the changes made in to the laboratory procedure by the improvement of the manual and the introduction of pre-labs.

These post-labs can also be seen at the end of each pre-lab in the same Appendix-C.

The pre-lab sheet developed for the Michelson Interferometer is shown below as a specimen.

5.3.3 PRE-LAB: THE MICHELSON INTERFEROMETER

Pre lab:

The following preparatory work for this experiment should be done **before you come to the lab.** Your demonstrator will check that this has been done.

What does it do ?

The Michelson Interferometer produces interference fringes between two beams of light which have travelled along different paths. The interference pattern depends on the difference in the lengths of these paths. The instrument can be used to measure small distances ~10^{-10}m, much smaller than anything visible with the naked eye or optical microscope. The micrometer in the instrument can only measure distances greater than about 10^{-5}m, but interference techniques are used to increase its sensitivity by 100,000.

What will I measure ?

You will measure,

(1) The average wave length of the sodium D lines.

(2) The spacing between the two wave lengths of the sodium D lines and

(3) The refractive index of air.

How does it work?

Read the appropriate section in the manual.

The 5:1 reduction lever is hinged at the left end so that, when the micrometer moves the right end by 5mm, mirror M1 moves by 1mm. Thus the distance moved by M1 equals the change in reading on the micrometer divided by 5.

What do I do ?

-Check that the lever ratio is 5:1.

-Obtain fringes with mercury light.

-Obtain fringes with white light. These occur when the path difference is 0.

-Measure the average wave length of Sodium D lines, and their separation.

-Measure the refractive index of the air.

What should I know before I begin ?

-How the Michelson Interferometer works

-What is meant by optical path length ?

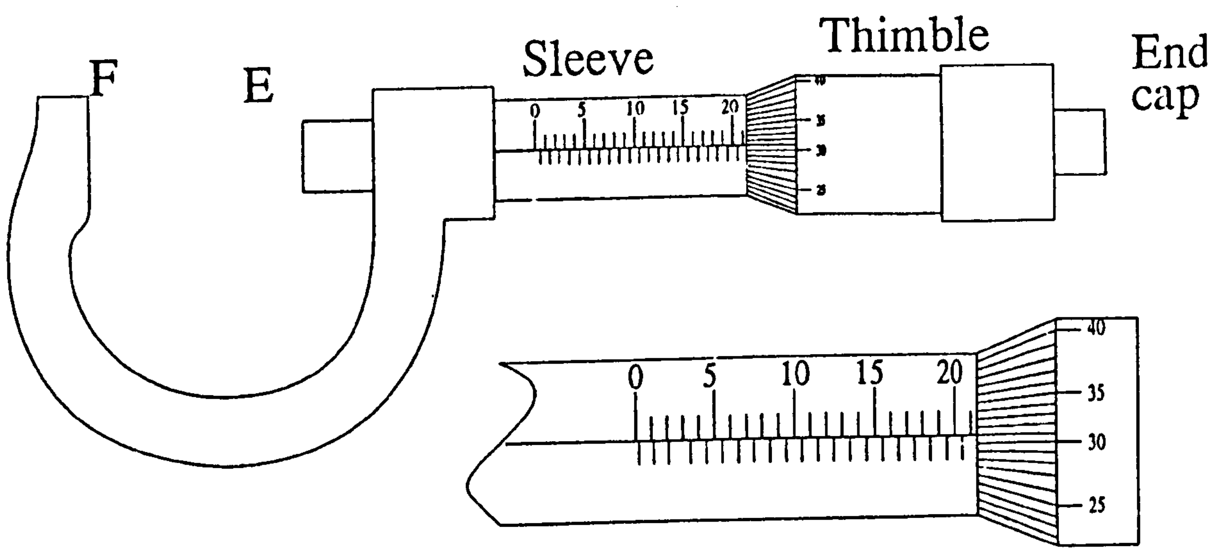
-How to read the micrometer scale (See the enclosed page. There are computer aided training packages on the Acorn network.)

-What is the accepted value of the wavelength of the sodium D lines ? ________

-What is the refractive index of air ? ________

MICROMETER SCREW GAUGE

Figure1.



A typical micrometer is shown in figure (1).

The end cap, thimble and moving face E are connected and screwed into the sleeve of the instrument. The object to be measured is placed in contact with face F, and face E moved into contact with it by turning the end cap. The thimble is connected to the end cap by a ratchet so that excessive force cannot be applied to the object.

The length of the object is equal to the length of datum line exposed by the thimble. The datum line is graduated with two sets of marks, the set above the line reading in mm and the set below reading in half mm. In the diagram, the reading is between 21.0mm and 21.5mm because the 21mm mark is visible but the 21.5 mark is hidden by the thimble.

The scale on the thimble gives decimal fractions of a mm. One complete revolution of the end cap corresponds to a movement of 0.5mm. The thimble scale is marked in 50 equal divisions, figured in five's so that each small division on the thimble represents 1/50 of 1/2mm which equals 1/100 mm (0.01mm). In the diagram, the datum line intersects the thimble scale at 31. The exact reading is then 21.31mm.

In figure 2, the main scale reading is more then 21.5 but less than 22.0. The thimble reading is again 31 so the total is 21.5 + 0.31 = 21.81mm.

Figure 2.

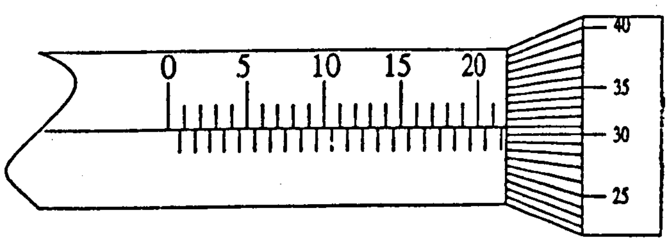
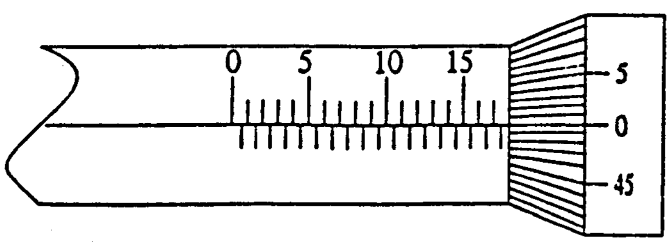


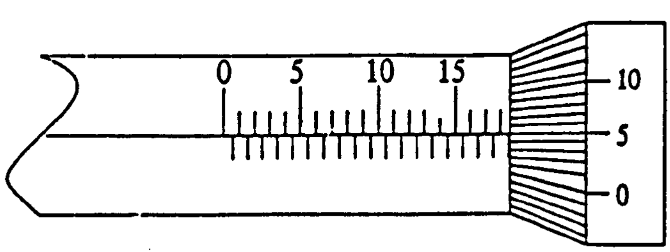
Figure 3.



What is the reading in this figure?

Ans.:-------------------

Figure 4.



What is the reading in this figure ?

Ans.:-------------------------

POST-LAB MICHELSON INTERFEROMETER

You should do the following work after you have written up the experiment in your record book.

1. Having measured the value of the sodium D lines, how would you explain the size to a layman in terms of some thing he would recognise and appreciate ? Write it in a few sentences.

2. In streets lit by sodium lamps, why do all cars (except yellow ones) look black ? Write an explanation.

3. You are given a drinking straw, a needle and a 10mg weight, find the approximate mass of a hair. Describe your method and give a result.

4. Measure the thickness of a page in your text book by two methods and compare the values offering an explanation for any disparities.

5.3.4 ATTITUDE

The term **attitude** is very broad and has been the subject of extended debate. Researchers have used it in many different contexts without reaching a consensus.

Thurstone, (1929), described attitude as "the degree of positive or negative affect associated with some psychological object".

Bloom, Krathwohl and Masia, (1964), characterised the thought, feeling and action dimensions of human development into the cognitive, affective and psychomotor domains as a way of describing the process of internalisation.

According to Krech and Cruthfield, (1946), "an attitude can be defined as an enduring organisation of motivational, emotional, perceptual, and cognitive processes with respect to some aspect of the individual's world". this definition emphasising the aspect of learning and problem solving. Allport, (1935), declared that an attitude is a mental and neural state of readiness, organised through experiences, exerting a directive and/or dynamic influence upon the individual's response to all objects and situations with which it is related. Katz and Stotland, (1959), have analysed attitude into three dimensions: (a) affective, (b) cognitive, and (c) behavioural components. The affective component consists primarily of negative and positive feelings which have been learnt. The cognitive component is the knowledge base of the intellectual process. The behavioural components refer to a measure of the physical response associated with attitude. Gardner, (1975), sub-divided science related attitudes into two major categories as: (i) Attitude to science, for example enjoyment, interests and so on. (ii)Scientific attitude, this refers to the styles which the scientists are presumed to display. Phase-I of this study intend to focus the attitude to science, specifically students attitude to physics-II laboratory work.

There is an open ended discussion in the literature regarding instruments/tools concerning attitude measurements which have been criticised because new instruments enclose new variables and introduce new definitions of established ones. Despite criticisms and disagreements there are a number of well established methods of attitude measurement available. Such as Likert, (1932), Osgood's, (1955), Semantic Differential, [illegible] (1929). All of them have advantages, but to suit the purpose of this research study and for ease of administration, the Likert five-point scale method was chosen. Care was taken not to treat the data as cardinal, but as ordinal and to apply chi-square test only on the results.

THE ATTITUDE (PRESENT STUDY)

The questionnaire was developed by the researcher against the objectives already set out in chapter four and the hypotheses developed in the background of the Information Processing Model of learning science as already discussed in section 5.2. The questionnaire was composed of twenty one items, of which one item was different, seeking information, about whether the student had attended the relevant lectures on the experiment or not, because some students had to do the experiment before the relevent topic/material was covered in lectures.

In fact out of twenty, only ten items are original questions, while the remaining ten items are the negative form of first ten items, to check the consistency of response. The attitude questionnaire is presented here.

PRACTICAL EVALUATION

Title of the Experiment ______________ Name ______________

This experiment is seeking information about your reaction to the experiment you have just completed. Your response will not affect your assessment in any way. Please tick the appropriate box to indicate the extent which you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Neutral	Dis agree	Strongly Dis agree
	1	2	3	4	5
1. This experiment was easy to do.					
2. The purpose of this experiment was very clear to me when I started the lab work.					
3. For this experiment it was easy to use the apparatus.					
4. Having done this experiment I now find the topic more interesting.					
5. The preparation I did before coming to the lab was enough, and helped me to understand what I was doing.					
6. It was easy to follow the lab manual.					
7. The experiment helped me to understand some of the course work.					
8. I successfully completed this experiment within the prescribed time.					
9. Experimental procedure was much clearer due to my preparation.					

10. Having done this experiment, I can see how to apply my knowledge in other contexts.					
11. I found this experiment, was difficult.					
12. When I started this experiment, I didn't know what its purpose was.					
13. Apparatus used in this experiment was difficult to handle.					
14. My preparation for this experiment made me not interested in the subject.					
15. I need more information on to how to prepare for this experiment.					
16. The whole procedure was not clearly explained in the lab manual.					
17. Preparation for this experiment not contributed to my understanding of the course.					
18. Not enough time was given to complete the experiment.					
19. Preparation for the lab was not very helpful in following the experimental procedure.					
20. I could now do a similar experiment on my own without further instructions.					
21. Have you studied this topic in your lecture course this year?					

In the questionnaire, items number, one and eleven, three and thirteen, six and sixteen were intended to show if this teaching approach helped the students to improve their understanding to the experiment.

Item numbers, two and twelve were intended to find out if the purpose of the experiment was clear to the students with pre-lab/with out pre-lab.

Item numbers, four and fourteen were intended to find out whether the use of pre-lab increased the interest of the student in the experiment or not.

Item numbers, five and fifteen, nine and nineteen were included to find out if as was expected, the pre-lab exercise helped students to understand better the experimental procedures and the concepts involved.

Item numbers, seven and seventeen were intended to test if the practical work with pre-lab contributes to the understanding of the lecture course.

Item numbers, eight and eighteen studied the difference in speed of successful completion, between the "with pre-lab" and "without pre-lab" method of the experimental work.

Item numbers, ten and twenty were intended to find out if the student's confidence in the application of knowledge was increased by pre-lab.

The questionnaire was the same for all the experiments.

5.4 EXPERIMENTAL DESIGN AND PROCEDURE

5.4.1 SAMPLE

One hundred, second year physics-II undergraduates of Glasgow University were the sample for this study during phase-I. However, some students transfered to another course and due to the difficulties of getting all of the students to follow and complete every single procedure applied in this research, only ninety five students eventually made up the total number, since they had fully completed the procedure for the present study during academic session 1994-95.

The researcher kept a record for each student, displaying their performance and achievements in every single procedure applied.

Later on the data was divided into groups according to cognitive styles of learning, that is Field-dependence/field-independence, of the students.

5.4.2 CONTENT OF STUDY

Five experiments were selected for the present study from the second year syllabus of the Department of Physics and Astronomy. The written instructions presented in the lab-manual were revised for the selected five experiments. The experiments are. (1) RESONANCE, (2) X-RAYS, (3) LASERS, (4) MICHELSON INTERFEROMETER, (5) ORBITAL DYNAMICS.

Actually the experiment on "orbital dynamics" was not taken into consideration when drawing up the statistical treatment because the nature of this experiment is different from that of the other four. It is concerned with computer and computational procedures, and so students don't need to do any physical or technical handling as was necessary for the other experiments. However pre-labs for all the five experiments were developed as explained in section 5.3.2 of this chapter. The pre-lab for orbital dynamics was supplied to all the students as a universal benefit for the sample.

5.4.3 TIME TABLE

The laboratory capacity was one hundred. Students came in five groups, once per week, for three hours. Approximately twenty five students came on each of Monday, Tuesday, Thursday and Friday for three hours (from two to five p.m.) to the physics-II laboratory during the whole of Phase-I (academic session, 1994-95) in two terms.

In three rooms of the laboratory, six sets of equipment for each experiment were set up so that up to six students could easily perform the same experiment simultaneously. Each student in the conventional approach was expected to do some preparatory work before he came to the lab. He was then allowed six hours in the lab to complete the practical work, taking two weeks in all. On the following week, the students were expected to have the experiment written up and ready for marking. There was also a great deal of flexibility in the system. for example, if a student was unable to attend one of his lab afternoons through illness, he was invited to attend on another afternoon as there were usually spare sets of equipment available.

Each experiment had a demonstrator to help the students on that experiment.

The presentation of pre-lab sheets to the sample/students was arranged in such a way that each student did half of his experiments without pre-lab (O), and half of the experiments with pre-lab (N), that is out of four experiments each student performed two experiments with pre-lab (N) and two experiments without pre-lab (O). The timetable was prepared and matched with the regular timetable of the physics-II laboratory course, which is presented on following page with further details.

TIME TABLE OF PHYSICS-II LAB (SAMPLE 1994-95-96)

The abbreviations used in this time table are.

M.I = Michelson Interferometer.

Res = Mechanical Oscillator and Resonance.

C = Orbital Dynamics and Resonance.

Las = Diffraction and Interference, Using Laser.

X = X-rays.

O = Old (with out pre lab).

N = New (with pre lab).

- Labs: on Monday, Tuesday, Thursday and Friday Only. Time = 2pm to 5pm.
- Each student will attend one afternoon per week.
- Groups should by four or six students.
- They work in pairs on X-rays and Resonance.
- Each student will attempt two of the experiments with pre lab (N) and two without pre-lab (O).
- All student will do computer experiment (C) "Orbital Dynamics and Resonance" with pre lab (N). The combinations are 20 rows with 6 possibilities, of these 4 possibilities have 3 rows, 2 possiblities have 4 rows. This combination is presented as under.

Pattern	Las.	Res	M.I	X	
1	N	N	O	O	3
2	N	O	N	O	4
3	N	O	O	N	3
4	O	N	N	O	3
5	O	N	O	N	4
6	O	O	N	N	3

- Chose alternating combination to have 4 rows.
- Student do other subjects. The labs are (loosely) organised in such away that students doing the same subjects did their lab at the same time. For example, all combined Physics and Maths students do their lab on Monday.
- Therefore, we try to implement as many of the above patterns as possible with Monday students, to avoid biases. this is presented on the following page.

MONDAY	WEEKS(4,5)	WEEKS(6,7)	WEEKS(8,9)	WEEKS(12,13)	WEEKS(14,15)	PATTERN
GROUPS						
1.	Las. N	Res. N	C. N	M.I. O	X. O	1.
2.	X. O	Las. N	Res. O	C. N	M.I. N	2.
3.	M.I O	X. N	Las. N	Res. O	C. N	3.
4.	C. N	M.I. N	X. O	Las. O	Res. N	4.
5.	Res. N	C. N	M.I. O	X. N	Las. O	5.
TUESDAY						
1.	Las. O	Res. N	C. N	M.I. O	X. N	5.
2	X. N	Las. O	Res. O	C. N	M.I. N	6.
3.	M.I. O	X. O	Las. N	Res. N	C. N	1.
4.	C. N	M.I. N	X. O	Las. N	Res. O	2.
5.	Res. O	C. N	M.I. O	X. N	Las. N	3.
THURSDAY						
1.	Las. O	Res. N	C. N	M.I. N	X. O	4.
2	X. N	Las. O	Res. N	C. N	M.I. O	5.
3.	M.I. N	X. N	Las. O	Res. O	C. N	6.
4.	C. N	M.I. O	X. O	Las. N	Res. N	1.
5.	Res. O	C. N	M.I. N	X. O	Las. N	2.
FRIDAY						
1.	Las. N	Res. O	C. N	M.I. N	X. O	2.
2	X. N	Las. N	Res. O	C. N	M.I. O	3.
3.	M.I. N	X. O	Las. O	Res. N	C. N	4.
4.	C. N	M.I. O	X. N	Las. O	Res. N	5.
5.	Res. O	C. N	M.I. N	X. N	Las. O	6.

5.4.4 DEMONSTRATORS

University teachers and post graduate (PhD) students from the Department of Physics and Astronomy, were selected as demonstrators in the physics-II laboratory during phase-I (academic session 1994-95) for the whole two terms.

A special lecture was arranged for the demonstrators to introduce them to this research work and their role in it to minimise bias.

An information sheet for the demonstrators was also prepared and supplied to them well in advance of the start of laboratory work. A copy of this sheet is shown in **Appendix-D**. Demonstrators were also requested to give their observations at the end of the term regarding the student's attitude and difference of learning with pre-lab (N) and with out pre-lab (O). Some of the demonstrators observations are presented in **Appendix-E**.

5.4.5 STUDENTS

Around three weeks in advance of the start of laboratory practical work, special lectures were arranged for the sample students, to inform them that the main purpose of this research was to improve their learning abilities. At the very beginning students were informed that, in addition to the lab manual, they are required to go through the pre-lab sheets for half of their experiments. It was also described to the students that there would be a random selection of experiments for each student, and each student would be given an equal chance to do his/her experiment with pre-lab (N) and without pre-lab (O) methods.

On the top of each pre-lab sheet it was mentioned that "The following preparatory work for this experiment should be done **before you come to the lab**. Your demonstrator will check that this has been done". The pre-lab sheets were supplied to the students at least one week in advance of their experiment.

5.4.6 QUESTIONNAIRE

After one week of the completion of each experiment all the students were required to fill in the questionnaire (the same as described in section 5.3.4 of this chapter) and return it to the researcher before they started their next experiment. The completed questionnaires were collected and kept in to the separate record files of each student, as those with pre-lab practical work, (N) new method, and those with out pre-lab practical work, (O) old method.

This procedure was continuously followed during the two terms of whole first phase of this study. At the end of the phase-I the data was analysed and the results are presented in the next chapter.

At the end of the second term of phase-I, the data was divided into the groups according to the cognitive style, (field-dependence or field-independence) of the participants for further processing.

5.5 FIELD-DEPENDENCE/FIELD-INDEPENDENCE GROUPS FORMATION

As explained before, the field-independent students are adept at separating signal from noise and so the pre-lab sheets are expected to make little difference to them. Field-dependent students should, however, benefit considerably.

5.5.1 HOW TO MEASURE F.D AND F.I

A test **SHAPES**, the Hidden Figure test (HFT), was administered to the sample, towards the end of the second term of phase-I, i.e. during the academic session 1994-95. The Purpose of applying this test was to measure the degree of field-dependence/field-independence of each student in the sample.

The sample was then divided into three groups according to their level of field-dependence/field-independence measured from **SHAPES** using both the extreme limits of field-dependence and field-independence cognitive styles.

To separate the sample into the categories of field, the researcher intended to use a formula. This formula as a criterion is used by Scardamalia, (1977), Case, (1974), Case and Golberson, (1974), Al-Naeme, (1991), and by other researchers. According to the formula (criterion) students with a score of at least a half standard deviation above the mean score of the sample population are considered to be in the category of field-independents, The students/subjects who have a score less than a half standard deviation below the mean score are classified as field-dependent. And the students/subjects between these two categories are field-intermediates.

$$F.I \geq \mu + \frac{1}{2}(\partial)$$

In mathematical terms: $$F.D \leq \mu - \frac{1}{2}(\partial)$$

$$F.Int = \mu \pm \frac{1}{2}(\partial)$$

In practice students in the bottom third of the group were classified as field-dependent while those in the top third were field-independent.

The number of students who fall into each group are shown in chapter six the "RESULTS AND DISCUSSION".

5.5.2 HIDDEN FIGURE TEST/SHAPES

In the past a Hidden Figure Test (HFT) was developed at the Centre for Science Education, Glasgow University, and based on Witkin and his followers' work, (1974, 1978, 1979, 1981). The test items were designed and used by El-Banna, (1987) for the first time; the same test was used by Al-Naeme, (1991), and other researchers. This (HFT) is composed of eighteen complex figures, apart from two figures used for examples. There were six simple shapes which were embedded in the eighteen complex figures (only one simple shape in each figure) and the subjects had to isolate these shapes.

Two examples were used in the first two pages of the test booklet, six simple shapes were located in the third page of the booklet as a specimen of the type to be found. Subjects were required to find a hidden simple shape in each complex figure. They had then to outline it in pencil or pen against the lines of the complex figure. There were some conditions in the HFT which were had to be followed.

The Hidden Figure Test wich was used in this study had been revised under the supervision of Dr. Peter MacGuire. The revised version of HFT is named "SHAPES" and is now available for the use of researchers at the Centre for Science Education, Glasgow University. The test is presented in the **Appendix-F**.

The test "SHAPES" is composed of twenty items (complex figures), apart from two other figures used for examples. There are eight simple geometric and non geometric shapes, which are embedded in twenty complex figures.

On the first two pages of the test booklet, two examples are presented. The specimen simple shapes are shown on the last page of the booklet.

From the third page, the arrangement of twenty items (complex figures) is based on an easy to complex approach .i.e. the first four items have low difficulty level then the next four have high difficulty levels, and the next four complex figures have a low difficulty level then the next items are difficult and so on until twentieth item. This is the important approach, used by Witkin and his followers.

Time specified for this test is fifteen minutes all together, five minutes for examples, to read and understand the instructions, and ten minutes for the twenty items, i.e. half minute to trace one simple shape into the each complex item. The subjects are required to outline the simple shape in pen/pencil in the lines of the complex figures.

5.5.3 NECESSARY CONDITIONS OF 'SHAPES'

The students were required to trace the simple shapes from the complex figures within certain conditions which are described here.

1. The simple shape when it appears within the complex figure is always the same size, has the same proportion, and faces in the same direction as it is shown alone, on the last page of the booklet.
2. There are many simple shapes embedded in each complex figure, but the simple shape which is required appears only once. Thus the students were required to trace the particular simple shape in to the particular complex item, exactly as it is shown in the last page of the booklet.
3. The students were not allowed to use any means to measure the size of the simple shape embedded in the complex figure.
4. The students were allowed to refer to the last page of simple shapes as often as necessary.
5. Strictly fifteen minutes were allowed for this test.

5.5.4 SCORING

Apart from first two examples, the first four (complex figures) items of the test were used as practice items. The sixteen remaining items were used for scoring.

The main scoring scheme which is used for the "SHAPES" Hidden Figure Test is to give one point for finding a correct simple shape embedded in a complex figure. The overall sum of these scores is the total marks which an student can gain. The possible maximum score that can be obtained is sixteen.

5.6 PHASE-II (1995-96) THE COGNITION

The second phase of this study is named **COGNITION**. This phase extended over the academic session, 1995-96, and focused on the student's understanding of the content of the physics-II laboratory work.

During this phase the following points were under scrutiny: (i) pre-lab improvement in the light of Phase-I experiences (2) Development and meaningful use of the post-lab in the light of the course objectives.

5.6.1 PRE-LAB IMPROVEMENT

An attempt was made to provide the students with a theoretical grounding before beginning the experimental work to extend their understanding of what they were to do. During the first phase the use of pre-lab revealed that, in some places, students still needed some clarification about the experiment.

Johnstone and Wham, (1982), have suggested that this may result in students not thinking about either the manipulative aspects of the experiment or the theory. In the event, they opt to follow the experiment's procedures without thinking about what they are doing or why they are doing it.

Meaningful practical work is not possible without a strong theoretical base and also a mastery of laboratory techniques. If students are familiar enough with the theory and the techniques involved, they are effectively free to think about what they are doing.

The pre-lab work was aimed at improving the students' perception of the task by building upon existing understanding and making it readily available for recall to facilitate meaningful learning. Once the technique and experimental content are mastered, students are free to use all their working memory space to solve practical problems in a post-lab. The students are then not given a **recipe** or instruction to follow and so must think for themselves within the content of knowledge and understanding they have already gained in the formal labpratory.

The pre-lab sheets for each experiment used in phase-I (1994-95), were improved for further use in the physics-II laboratory. For the experiment 'orbital dynamics' the pre-lab sheet was not changed as it seemed to perform its function well. The other four pre-lab sheets were changed. Mostly under the same previous headings in the pre-labs, some additional information was provided where it was necessary and post-labs were omitted from the end of each pre-lab, as this time post-labs were developed separately and used in its real meaning after the completion of each experiment. A complete set of pre-labs used during phase-II (1995-96), is shown in **Appendix-G**.

5.6.2 POST-LAB

Post-lab was introduced in this study to allow students to re-explore what they had learned in the laboratory and use it to solve some relevant practical problems. It was hoped that by attempting and succeeding in the post-lab work they would lay down richer and better interlinked material in long-term memory, i.e. meaningful learning.

During the first phase of the present study we used mini post-labs at the end of each pre-lab sheet. The result was encouraging as the student behaviour towards post-labs was exciting and full of interest. This would be likely to make them organise and plan their own day to day problem solving techniques similar to the experiment. They also seemed to agree that such types of exercise should be more frequent and would be helpful in remembering.

Post-labs give students the opportunity to plan and design their own strategy and draw conclusions from experimental results, think independently and develop skills in solving problems presented in the post-lab sheets.

Post-lab problems were chosen from every-day life, to develop student's interest in physics, to engage them more and relate the subject to their own experiences, which can help them to develop a better understanding of the subject (experiment).

The post-lab was to be done within one week of the completion of each experiment and before the start of the next experiment. Post-lab developed for the experiment, "X-rays" is presented on the next page as an example. A complete set of post-labs developed and used in this study is shown in **Appendix-H**.

5.6.3 SPECIMEN POST-LAB

NAME:__________

POST-LAB X-RAYS

The following questions will help you to consolidate the work you did in the lab and help us to improve the lab manual. Please answer them carefully.

Tick the true statements:

1. (a) Photons of wave length 500nm are visible.

   (b) Photons of wave length 5000nm are x-rays.

   (c) Photons of wave length 5nm are x-rays.

   (d) Photons of wave length 0.005nm are x-rays.

2. (a) Photons of energy 2.5 ev are visible.

   (b) Photons of energy 25 ev are x-rays.

   (c) Photons of energy 250 ev are x-rays.

   (d) Photons of energy 0.025 ev are x-rays.

3. Sodium fluoride forms cubic crystals with lattice spacing 'a'. Tick the correct value for 'a'.

   (a) a=0.0023nm (b) a=0.023nm (c) a=0.23nm

   (d) a=2.3nm (e) a=23.0nm

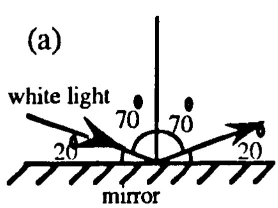
4. A beam of x-rays of intensity 1 is reduced to an intensity of 0.8 when it passes through 1mm of lead. If it passes through 2mm of lead, its intensity will be reduced to:

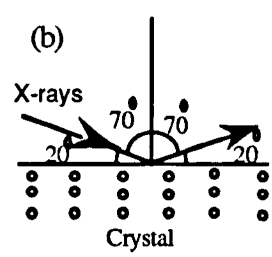
(a) 0.6 (b) 0.64 (c) 0.5 (d) 0.7

5. An x-ray beam of unit intensity has its intensity reduced by 0.4 when passed through 2mm of Copper. When passed through 4mm of Copper its intensity is reduced by:

(a) 0.8 (b) 0.64 (c) 0.6 (d) 0.16.

6. Look at the figures (a) and (b) :





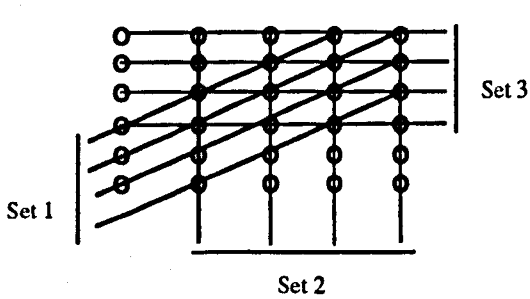
(a) What is the angle of incidence?

Answer is ___________

(b)What is the angle of incidence?

Answer is ______________

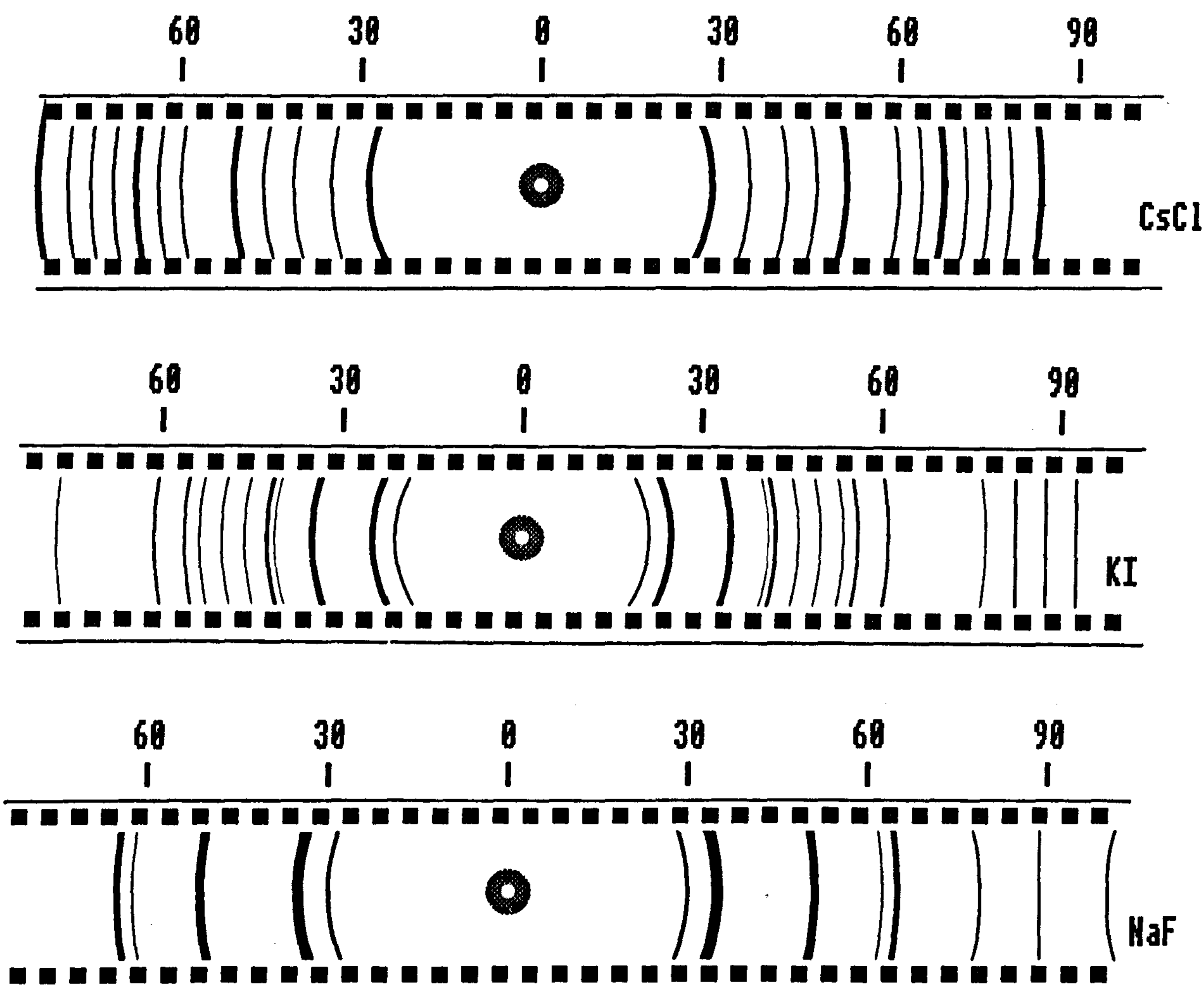
7. In diagram (b) above, which sets of crystal planes give Bragg reflection?



Tick the correct answer. (a)Set 1 (b)Set 2 (c)Set 3

8. In real life, it is often very difficult to obtain a single crystal suitable for use in a spectrometer. Instead, a powder photograph of very large number of minute crystals orientated at random can be used as the target. A few of these crystals will happen to be orientated correctly to satisfy the Bragg conditions for any set of planes. Cones of high intensity are formed with the original x-ray beam as axis. These are recorded on a photograph shown as under. Two crystals with the same structure give identical pattern of dark and faint lines, but the angular scale is different because the spacing is different.

figure



What can you say about the structure of NaF.

(a) Same as the pattern for KI. (b) Same as the pattern for CsCl.

(c) Different from both of the above patterns (a) and (b).

5.7 EXPERIMENTAL DESIGN AND PROCEDURE

During the **COGNITION**, phase-II (academic session 1995-96) more or less the same procedure was followed as we did in phase-I. However some minor changes were made according to the demand of design and situation of phase-II, these are described here step by step.

5.7.1 SAMPLE

During phase-II, the student sample was again the physics-II laboratory students of Glasgow University. This time the number of students was eighty five. Due to the difficulties of getting all of the students to follow and complete every single procedure applied in this research, only seventy four students eventually made up the total number, since they had fully completed the procedure for the completion of the present study during academic session 1995-96.

The researcher intended to keep a record for each student displaying their performance and achievements in every single procedure applied. Later on this sample was also divided (as it was divided in phase-I) into groups according to their cognitive styles of learning, that is Field-dependence/field-independence.

5.7.2 CONTENT OF STUDY

The same experiments of the physics-II laboratory were chosen for this part of study as had been used in phase-I, during academic session 1994-95.

5.7.3 TIME TABLE

The same time table was followed as for the academic session 1994-95; the only change we made was to match it with the new regular time table of physics-II laboratory. This time again each student did half of his experiments with pre-lab and half of his work without pre-lab.

5.7.4 DEMONSTRATORS

Again University teachers and postgraduate (PhD) students from the Department of Physics and Astronomy, were the demonstrators in the physics-II lab, during the **COGNITION** the phase-II, academic session 1995-96.

As in the first phase, a special lecture was arranged for the demonstrators to inform them about this research work and their role of assistance to minimise the biases. Advice for the demonstrators was also prepared and supplied to them well in advance of the start of laboratory work. A copy of this advice is shown in Appendix-I (same as explained in the section 5.4.4 of this chapter).

Demonstrators were also requested to give their observations at the end of the term regarding the student's attitude and any differences of learning comparing pre-lab (N) and without pre-lab (O) of teaching in the lab. Some of the demonstrators observations are presented in Appendix-E.

This time a questionnaire was also developed and supplied to the demonstrators, to record information about each group of students whom they supervised. The purpose of this questionnaire was to verify that the students had used the pre-lab sheets before they came to the laboratory.

5.7.5 STUDENTS

The information supplied to the students was similar that in phase-I. Well before the starting time of the laboratory work, special lectures were arranged to inform the students that the main purpose of this research was to improve their learning abilities. In addition to the lab manual, it was explained that each student was required to go through the pre-lab sheets for half of the experiments.

There was a random selection of the experiments for each student and an equal chance was given to each student to perform half of the experiments with pre-lab (N) and half of the experiments without pre-lab (O) methods.

As before during phase-I, the pre-lab sheets were supplied to the students at least one week in advance of the experiment.

They were also informed that they would be required to do the post-lab work after one week of the completion of each experiment, and to return the completed post-lab sheets before the start of the next experiment.

This procedure was followed throughout the two terms of phase-II during academic session 1995-96.

5.7.6 GROUPS FORMATION

Similar to the phase-I, towards the end of second term of the academic session 1995-96, the Hidden Figure Test **SHAPES** was administered, to divide the sample students into the groups of field-dependence/independence, according to their cognitive style of learning.

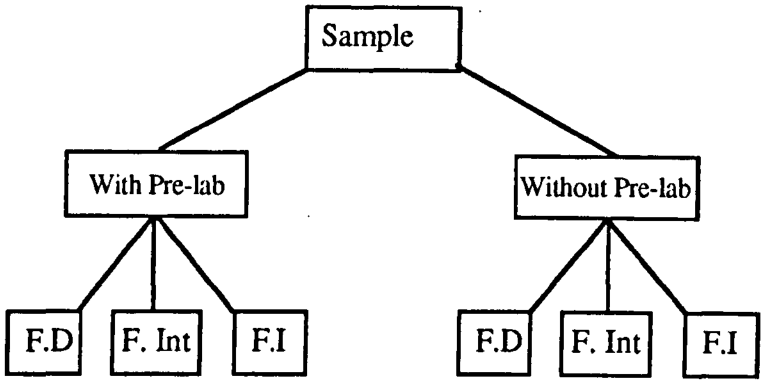
SHAPES is the same test which has already been explained in the section 5.5.1 of this chapter and shown in Appendix-F.

As before the student were divided into three groups i.e. field-dependent, field-independent and field-intermediate. Later on, learning aspects were analysed for each group and results are reported into the chapter six under the heading of "RESULTS AND DISCUSSION".

5.8 SUMMARY

PHASE-I

ATTITUDE

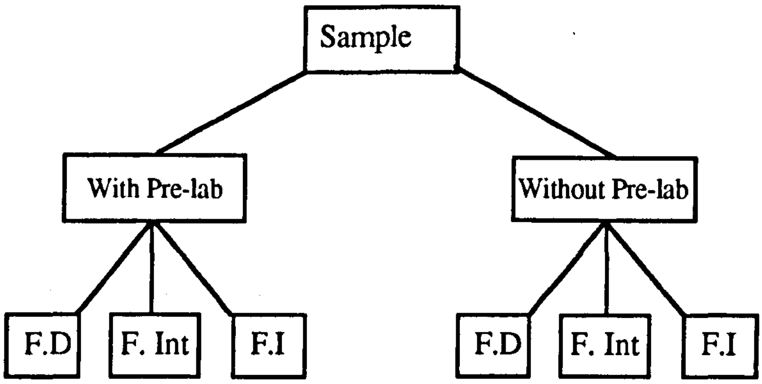


Attitude Questionnaire Administered

Post-Labs Not Compulsory

PHASE-II

COGNITION



Post-Labs Compulsory To Test Learning Gain

Physics-II laboratory students, during the academic session 1994-95-96, are the sample for this research study. University teachers and post graduate (PhD) students from Department of Physics and Astronomy were the demonstrators. Each group of up to six students was supervised by one demonstrator.

The research methodology is composed of two phases, one is named as **attitude phase** and the second phase is considered as **cognition phase**.

The attitude phase extended over a period of two terms and covered the academic session 1994-95. This phase focussed on students attitude to the changes made in the laboratory procedure. For the first phase the standard lab manual was improved, Pre/post-lab was introduced and a questionnaire was used as a tool to measure the students' attitude. Towards the end of second term of the phase, the Hidden Figure Test, **SHAPES** was administered to divide the sample of students into the groups according to their cognitive style of learning field-dependence/field-independence.

The **cognition**, second phase of this study is extended over the two terms of academic session 1995-96. This phase focussed on students understanding to the physics-II laboratory work (Experiments). For this period pre-labs were improved, post-labs were developed and used to measure the students' understanding up to the levels of comprehension, application, synthesis and analysis at one end, on the other side it was also aimed to measure the difference of students performance with pre-lab and without pre-lab work in the physics-II laboratory. Similar to the phase-I this time again the Hidden Figure Test, **SHAPES** was administered to divide the sample students into the groups according to their cognitive style of learning field-dependence/field-independence.

The time table and procedure employed for both the phases was such that each student performed half of his experimental work with pre-lab and half of his experiments without pre-lab. So the difference of achievement can be analysed.

CHAPTER SIX

RESULTS AND DISCUSSION (PHASE-I)

6.1 INTRODUCTION

The practical part of this study involves attempting to find out the students' **Attitude** towards the changes made in the physics-II laboratory and the **Cognition**, student understanding of physics-II practical work related to their cognitive style of learning field-dependence/independence and their pre-lab experience. The results are spread over two major parts that is **Results of the Attitude Phase** and **Results of the Cognition Phase.**

In this chapter attention will be paid to the Results of the Attitude Phase (academic session 1994-95). An attempt was made to find out the students' attitude to physics-II practical work with pre-lab (N) and without pre-lab (O) from different aspects. The overall students' attitude to the physics-II laboratory and the attitude within their cognitive styles of learning, (field-dependence/independence) was measured, thereby, to test the hypotheses (particularly hypotheses one and two), raised in chapter five.

The results are presented here in three parts. The first part displays the **Attitude Questionnaire Results** of the sample towards the changes made in the physics-II laboratory procedure and the significance of the use of pre-labs. The second part describes the **Laboratory Results,** the score made by students in their experiments with pre-lab and without pre-lab methods. And the third part is reflecting the **Over All Physics-II Results,** the students' performance in class tests, degree exam, library project and free range experiment.

6.2 ATTITUDE QUESTIONNAIRE RESULT

As described in the last chapter an attitude-questionnaire was developed, aimed to measure the students' attitude to the changes made in the physics-II laboratory during phase-I (academic session 1994-95). The questionnaire was composed of twenty items and an additional item to find out if the students had had any lecture related to the experiment at all. The twenty items were divided into two parts. The first part was composed of ten statements, that is items number one to ten, asking about different dimensions of the experiment; such as understanding, speed of completion, application of knowledge, ease, procedure understanding, increased interest and purpose of the experiment. The second part was composed of ten statements, from item numbers eleven to twenty. These were the negative form of the first part, aimed to check the consistency of the responses.

The dimensions to be measured by each item are shown in the following table.

Table 6.1
ATTITUDE-QUESTIONNAIRE DIMENSIONS

DIMENSION	ITEM NUMBERS	FIVE POINT SCALE
Purpose	Two And Twelve	Strongly Agree to strongly Disagree
Understanding	Five and Fifteen, Seven and Seventeen	Same as above
Application of Knowledge	Ten and Twenty	Same as above
Ease	One and Eleven, Three and Thirteen, Six and Sixteen.	Same as above
Procedure	Nine and Nineteen	Same as above
Increased Interest	Four and Fourteen	Same as above
Speed of Completion	Eight and Eighteen	Same as above

6.2.1 RELIABILITY OF ATTITUDE-QUESTIONNAIRE

Before analysing the students' attitude, it is necessary to determine the reliability of the attitude-questionnaire. Many statistical methods are available for estimating reliability, the "internal consistency method" was chosen, since this was the most convenient procedure to apply on this five point scale attitude-questionnaire. We used the chi-square test for the items employed.

The attitude questionnaire was composed of two parts; the first part consisted of positive statements, from item numbers one to ten. The second part was a negative form of the statements of the first part and consisted of items number eleven to twenty, aimed to check the consistency of the responses in first part. It was administered after one week of the completion of each experiment throughout the two terms of phase-I, the academic session 1994-95.

Total responses (frequencies) of item number eleven within the five point scale i.e. from strongly agree to strongly disagree, was matched with the total responses of item number one. (We turned the total responses of item number eleven as the statement was a negative form of the statement in item number one). This was employed until item number twenty. Then a chi-square test was applied for each two sets of responses such as, one and eleven, two and twelve, three and thirteen and so on, to determine the significance of the difference between the frequencies of the two items and the results are presented in table 6.2.

The significant difference of the paired responses between two similar sets of items gave us a clear picture of the extent to which they measured, consistently.

Table 6.2
THE CONSISTENCY OF RESPONSES

Q:Nos	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	CHI-SQUARE Tabulated Value At 5% LOS=9.49, And 1%LOS=13.28, df=4
1	10	143	114	62	11	
11	18	150	93	66	13	4.875<T.V
2	10	138	98	83	11	
12	17	148	96	79	10	2.187<T.V
3	26	148	97	53	15	
13	22	171	78	52	16	4.096<T.V
4	9	106	155	60	10	
14	7	93	190	44	6	8.112<T.V
5	5	102	153	73	6	
15	6	112	122	90	10	6.824<T.V
6	10	153	105	66	6	
16	12	97	157	73	11	24.730*>T.V
7	16	132	129	55	8	
17	18	118	130	70	4	4.039<T.V
8	60	181	31	54	15	
18	66	177	44	43	9	5.325<T.V
9	5	78	195	55	6	
19	6	93	192	45	5	2.51<T.V
10	7	102	174	53	5	
20	5	100	163	57	16	6.620<T.V

The null hypothesis is that there is no significant difference and that any difference is by chance. We are unable to reject this hypothesis with any certainty and so conclude that there is internal consistency except the pair 6 and 16. The dimension which is measured by item number six is also measured by items number one and eleven and three and thirteen, (table 6.1) and the calculated values in these two sets of items are less then the tabulated value, hence the inconsistency of the responses in the set of item number six and sixteen can be considered not to be serious.

We conclude that there is no significant difference in the consistency of responses between two parts of the attitude questionnaire and this supports the reliability of our attitude-questionnaire used in this study. Also the sum of all the frequencies in the **strongly agree** and **agree** responses are greater than the frequencies in the **strongly disagree** and **disagree**. This again confirms that questionnaire is working in the direction it was supposed to work. It is now safe to analyse the students' responses regarding each selected experiment separately.

6.2.2 SAMPLES' ATTITUDE TO EXPERIMENTS

It was described in the Methodology (section 5.4.3, page 104) under the heading of "time table" that each student in the sample performed half of his practical work with pre-lab and half without pre-lab. The researcher kept the students' record in separate files as (N) for the experiments done with pre-lab and (O) for the experiments done by the students without pre-labs. Simultaneously the attitude-questionnaire responded to by every student was also kept separately and analysed as (O) and (N) according to the method used to perform the physics-II experiment.

The questionnaire responses were analysed in two parts. The first part consists of ten questions and the second part consisted of a negative form of the first ten items. All the responses (frequencies) in on five point scale questionnaire were summed up separately by category then the scores (frequencies) of both parts were summed up according to the points of strongly agree to strongly disagree (the frequencies of item number eleven to twenty were inverted as the statements were negative to item number one to ten).

Since the only possible responses are the five given categories, ranging from strongly agree to strongly disagree, there are no intermediate categories. The frequency distributions of ratings resulting from the questionnaire were categorical data. The picture which emerged for each experiment is shown in the separate tables below.

Table 6.3
EXPERIMENT: MICHELSON INTERFEROMETER (N AND O)

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	4	55	30	5	0	
O	1	11	33	34	1	
2.N	7	52	29	6	0	
O	0	15	23	38	4	
3.N	9	46	27	8	4	
O	2	20	21	28	9	
4.N	2	33	48	10	1	
O	0	14	39	27	0	
5.N	1	48	33	12	0	
O	0	11	34	34	1	
6.N	0	59	29	6	0	
O	4	17	26	11	0	
7.N	8	46	29	11	0	
O	1	21	36	20	2	
8.N	23	62	5	0	4	
O	12	45	10	11	2	
9.N	0	40	51	3	0	
O	2	11	45	22	0	
10.N	4	49	34	6	1	
O	1	25	34	18	2	

In the table LOS = level of significance and df = degree of freedom.

According to chi-square test procedure, if one or more expected values turns out to be quite small (less than 5) the data in the contingency table must be collapsed. We can overcome this situation, by combining similar categories.

In the above table 6.3, some of the values are less than 5. This means that it is wrong to consider the results as having 4 degrees of freedom. Therefore instead, the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results in the table 6.3 (a), on the following page. The degrees of freedom are now 2, and the tabulated value of chi-square is 5.99 at 5% level of significance and 9.21 at 1% level of significance.

Table 6.3 (a)
EXPERIMENT: MICHELSON INTERFEROMETER (N AND O)

Q: Nos.	A	N	D.A	CHI-SQUARE Tabulated Value At 5%LOS=5.99 And At 1%LOS=9.21, df=2
1.N	59	30	5	
O	12	33	35	52.972>T.V
2.N	59	29	6	
O	15	23	42	53.072>T.V
3.N	55	27	12	
O	22	21	37	26.694>T.V
4.N	35	48	11	
O	14	39	27	15.643>T.V
5.N	49	33	12	
O	11	34	35	34.433>T.V
6.N	59	29	6	
O	21	26	33	36.013>T.V
7.N	54	29	11	
O	22	36	22	16.877>T.V
8.N	84	5	5	
O	57	10	13	9.326>T.V
9.N	37	51	6	
O	13	45	22	20.041>T.V
10.N	53	34	7	
O	26	34	20	14.454>T.V

The above table indicated that all the calculated values are greater than the tabulated values and there is strong significant difference between (N) with pre-lab and (O) without pre-lab responses, for every item of the questionnaire. It is apparent that students' attitudes changed positively when they performed Michelson Interferometer experiment with pre-lab (N).

experiment with pre-lab (N).

Now consider the sum of all the column responses separately, from strongly agree to strongly disagree for the Michelson interferometer experiment, in the table 6.3 (b).

Table 6.3 (b)
EXPERIMENT: MICHELSON INTERFEROMETER

Michelson Interferometer	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	58	492	315	65	10
Without Pre-Lab (O)	23	190	301	261	25

Calculated value of the above table is, $\chi^2 = 263.885$, with degrees of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, $\chi^2 = 13.28$ at the 1% level. This confirms that there is highly significant difference between the students' responses of with pre-lab (N) and without pre-lab (O) for the Michelson Interferometer experiment. The (N) frequencies are greater than the (O) frequencies in the positive direction and so it is obvious that the result is in favour of with pre-lab work.

In table 6.3 (b) and in many subsequent tables, the total number of responses for with pre-lab and without pre-lab are roughly equal but not identical. There are several reasons for this. The lab groups were not exactly the same size, ranging from 4 to 6. sometimes students were unable to attend the lab as timetabled because of illness, they had classes in another subject. Some questionnaires were not returned although every attempt was made to follow the students who made no return.

Table 6.4
EXPERIMENT: RESONANCE (N AND O)

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	5	45	30	6	0	
O	1	25	18	23	13	
2.N	1	43	24	18	0	
O	1	22	17	33	7	
3.N	7	46	27	6	0	
O	2	16	26	27	9	
4.N	2	18	46	18	2	
O	1	15	37	22	5	
5.N	0	36	35	15	0	
O	0	18	24	30	8	
6.N	5	34	28	19	0	
O	0	22	17	33	8	
7.N	1	43	32	10	0	
O	2	27	31	19	1	
8.N	11	43	11	17	4	
O	4	39	23	13	1	
9.N	1	25	55	5	0	
O	0	13	39	24	4	
10.N	3	42	33	8	0	
O	1	24	34	18	3	

In the above table some of the values are less than 5. It is wrong to consider the results as having 4 degrees of freedom. Therefore the same procedure was followed, as for the Michelson Interferometer experiment that is, "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results in the following table. The degrees of freedom are now 2.

Table 6.4 (a)

EXPERIMENT: RESONANCE (N AND O)

Q: Nos	A	N	D.A	CHI-SQUARE Tabulated value At 5%LOS=5.99 And At 1%LOS=9.21, df=2
1.N	50	30	6	
O	26	18	36	31.832>T.V
2.N	44	24	18	
O	23	17	40	15.926>T.V
3.N	53	27	6	
O	18	26	36	38.534>T.V
4.N	20	46	20	
O	16	37	27	2.249*<T.V
5.N	36	35	15	
O	18	24	30	17.838>T.V
6.N	39	28	19	
O	22	17	41	15.296>T.V
7.N	44	32	10	
O	29	31	20	6.223>T.V
8.N	54	11	21	
O	43	23	13	6.675>T.V
9.N	26	55	5	
O	13	39	28	22.900>T.V
10.N	45	33	8	
O	25	34	21	11.355>T.V

It is apparent from the above table that there is no significant difference between the O and N students' responses of item number four, which is measuring the students interest. However all other calculated values are greater than the tabulated values, and so there is a strong significant difference between (N) with pre-lab and (O) without pre-lab responses, for every item of the questionnaire in favour of the pre-lab.

Now consider the sum of all the responses from strongly agree to strongly disagree for the experiment Resonance, (N) with and (O) without pre-lab to determine the significance difference. It is shown in the following table.

TABLE 6.4 (b)
EXPERIMENT: RESONANCE (N AND O)

Resonance	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	36	375	321	122	6
Without Pre-Lab (O)	12	221	266	242	59

Calculated value of the above table is, $\chi^2 = 137.732$, with degrees of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, $\chi^2 = 13.28$ at the 1% level and $\chi^2 = 9.49$ at 5% level of significance. This confirms that there is significant difference between the students' responses of with pre-lab (N) and without pre-lab (O). And it is evidence of a positive change in students' attitude, when they performed Resonance experiment with pre-lab (N) method.

Table 6.5
EXPERIMENT: LASERS (N AND O)

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	2	32	36	14	2	
O	0	10	25	37	6	
2.N	5	44	26	10	1	
O	2	16	33	23	4	
3.N	6	49	21	9	1	
O	1	26	22	21	8	
4.N	3	26	40	15	2	
O	2	9	27	25	5	
5.N	2	33	38	13	0	
O	1	11	28	33	5	
6.N	2	53	23	8	0	
O	3	17	26	29	3	
7.N	3	34	34	14	1	
O	2	14	41	20	1	
8.N	8	48	11	16	3	
O	1	25	20	25	7	
9.N	1	28	42	12	3	
O	0	9	50	19	0	
10.N	3	32	33	17	1	
O	3	21	36	17	1	

Again the above table contains some values less than 5. Therefore we will continue the same procedure applied for last two experiments. This results the table 6.5 (a), presented on the following page.

Table 6.5 (a)

EXPERIMENT: LASERS (N AND O)

Q: Nos.	A	N	D.A	CHI-SQUARE Tabulated value At 5%LOS=5.99 And At 1%LOS=9.21, df=2
1.N	34	36	16	
O	10	25	37	27.105>T.V
2.N	49	26	11	
O	18	33	27	21.572>T.V
3.N	55	21	10	
O	27	22	29	18.494>T.V
4.N	29	40	17	
O	11	37	30	11.450>T.V
5.N	35	38	13	
O	12	28	38	24.694>T.V
6.N	55	23	8	
O	20	26	32	30.600>T.V
7.N	37	34	15	
O	16	41	21	9.607>T.V
8.N	56	11	19	
O	26	20	32	16.551>T.V
9.N	29	42	15	
O	9	50	19	11.329>T.V
10.N	33	33	18	
O	24	36	18	1.795*<T.V

The above table indicated that there is no significant difference between **O** and **N** responses of item number ten, which is measuring the application of knowledge. However all other calculated values are greater than the tabulated values, and so there is a strong significant difference between (N) with pre-lab and (O) without pre-lab responses, for every other item of the questionnaire in favour of pre-lab.

Now consider the sum of all responses separately, in the columns from strongly agree to strongly disagree, for the groups of Lasers experiment (N)with and (O)without pre-lab and confirm the significant difference. This is shown in the following table.

TABLE 6.5 (b)
EXPERIMENT: LASERS (N AND O)

Lasers	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	35	379	304	128	14
Without Pre-Lab (O)	15	158	318	249	40

Calculated value of the above table is, $\chi^2 = 147.068$, with degrees of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, $\chi^2 = 13.28$ at 1% level. This confirms the significant difference between the over all students' responses of with pre-lab and without pre-lab work, for the experiment Lasers in favour of pre-lab.

Table 6.6
EXPERIMENT: X-RAYS (N AND O)

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	12	66	7	5	0	
O	3	42	28	9	2	
2.N	5	53	26	5	1	
O	6	31	16	27	4	
3.N	16	62	7	5	0	
O	5	54	22	3	0	
4.N	1	22	53	13	1	
O	1	13	48	21	1	
5.N	3	47	34	6	0	
O	1	20	39	21	3	
6.N	6	61	18	5	0	
O	1	37	32	11	3	
7.N	4	20	55	8	3	
O	0	14	46	23	1	
8.N	30	49	6	5	0	
O	12	43	14	12	3	
9.N	4	30	50	5	1	
O	2	18	54	9	1	
10.N	7	44	29	9	1	
O	1	28	40	15	0	

In the table 6.6 some of the values are less than 5. According to chi-square test procedure, it is wrong to consider the results as having 4 degrees of freedom. Therefore the same procedure was applied as we did in the other experiments. This results in the table 6.6 (a) on the following page. The degrees of freedom are now 2.

Table 6.6 (a)
EXPERIMENT: X-RAYS (N AND O)

Q: Nos.	A	N	D.A	CHI-SQUARE Tabulated value At 5%LOS=5.99 And At 1%LOS=9.21, df=2
1.N	78	7	5	
O	45	28	9	23.525>T.V
2.N	58	26	6	
O	37	16	27	23.736>T.V
3.N	78	7	5	
O	59	20	5	8.698>T.V
4.N	23	53	14	
O	14	48	22	4.012*<T.V
5.N	50	34	6	
O	21	39	24	22.808>T.V
6.N	67	18	5	
O	38	32	14	16.005>T.V
7.N	24	55	11	
O	14	46	24	8.065>T.V
8.N	79	6	5	
O	55	14	15	12.306>T.V
9.N	34	50	6	
O	20	54	10	4.584*<T.V
10.N	51	29	10	
O	24	40	15	8.607>T.V

The above table indicated that there is no significant difference between **O** and **N** students' responses of item number four, which is measuring the students interest and item number nine, measuring understanding of procedure. However all other calculated values are greater than the tabulated values. There is a strong significant difference between (N) with pre-lab and (O) without pre-lab responses, for the other items of the questionnaire. It is evidence that students' attitude changed positively when they performed X-rays experiment with pre-lab (N).

Now consider the sum of all the responses for the X-rays experiment (N)with and (O)without pre-lab and determine the significant difference. It is shown in the following table.

TABLE 6.6 (b)
EXPERIMENT: X-RAYS (N AND O)

X-RAYS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	91	463	288	51	7
Without Pre-Lab (O)	32	300	339	151	18

Calculated value of the above table is, $\chi^2 = 119.689$, with degree of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, $\chi^2 = 13.28$ at the 1% level. This confirms that there is high significant difference between the students' responses of with pre-lab (N) and without pre-lab (O) for X-rays experiment in favour of pre-lab.

TABLE 6.7
WHOLE SAMPLE ON ALL EXPERIMENTS WITH PRE-LAB AND WITHOUT PRE-LAB

Sum of all the four experiments	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	277	1709	1288	366	37
Without Pre-Lab (O)	82	869	1224	909	142

Calculated value of the above table is, $\chi^2 = 614.860.748$, with degree of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, $\chi^2 = 13.28$ at the 1% level and $\chi^2 = 9.49$ at 5% level of significance, this confirms that there is highly significant difference between the students' responses of with pre-lab (N) and without pre-lab (O) for over all four experiments, selected for this study.

We conclude that pre-lab has fostered a positive students attitude towards physics-II laboratory work.

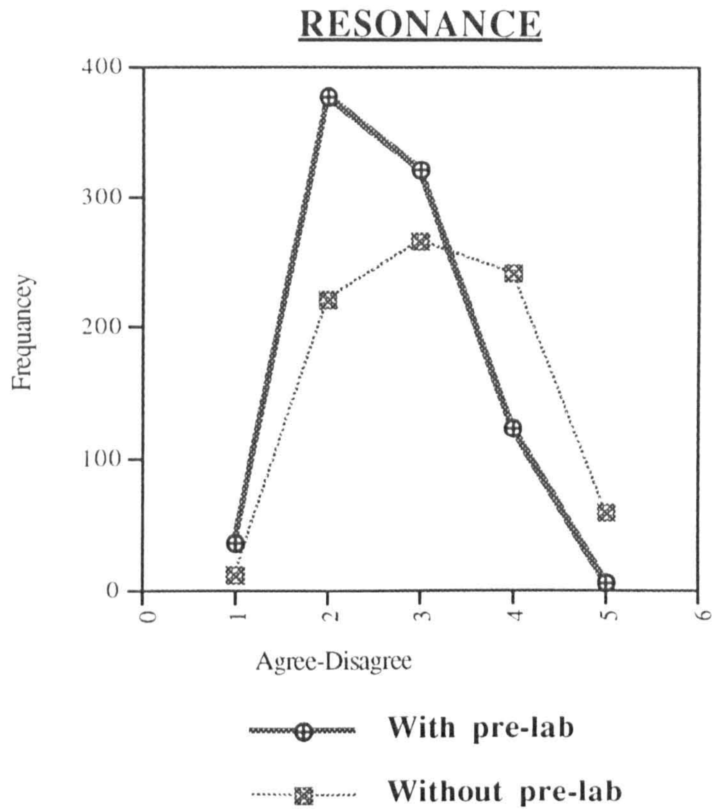
The item number twenty one of the attitude-questionnaire was considered and it was found that a very few students had had a relevant lecture before the experiment. Therefore the little data related to item number twenty one was not taken into the statistical process. All students were regarded as having had no previous lecture on the topic of the experiment.

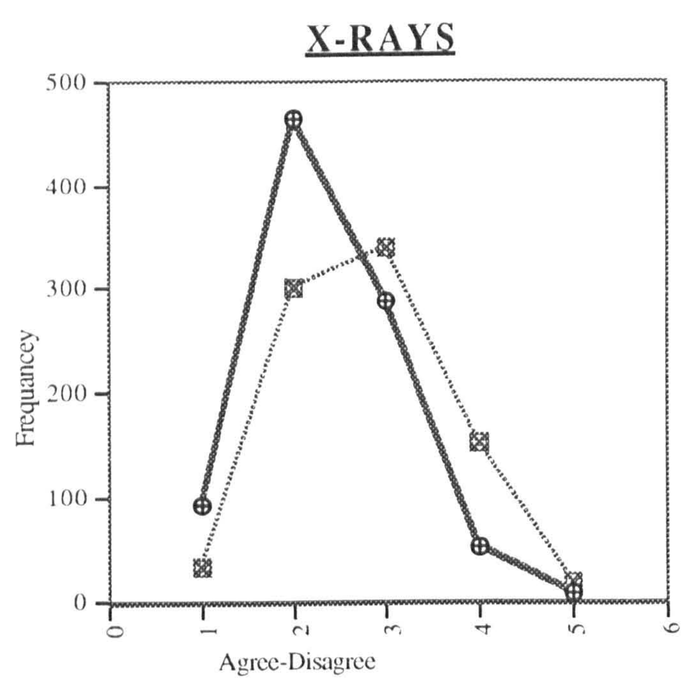
DISCUSSION

According to Howell, (1992), the calculation of the χ^2 value, using the formula $\chi^2=\Sigma\frac{(O-E)^2}{E}$, involve dividing by E, the expected value. If a particular value of E is very small, then the calculated value of χ^2 will be correspondingly increased, perhaps beyond the critical value. The conclusion that a statistically significant relationship exists may be based on this one particular small expected value.

The results of the above tables indicate that with reference to the attitude questionnaire, the pre-lab method employed during phase-I of this study, helped the students in general, and fostered their attitude to the experiments in the physics-II laboratory, during academic session 1994-95.

To gain further insight between the relationship of with pre-lab (N) and without pre-lab (O) practical work at physics-II lab, the graphs of each separate experiment from the processed data (explained in the last section) is shown on the following pages.


RESONANCE
400
300
200
100
0
Frequancey
0
1
2
3
4
5
6
Agree-Disagree
With pre-lab
Without pre-lab


X-RAYS
500
400
300
200
100
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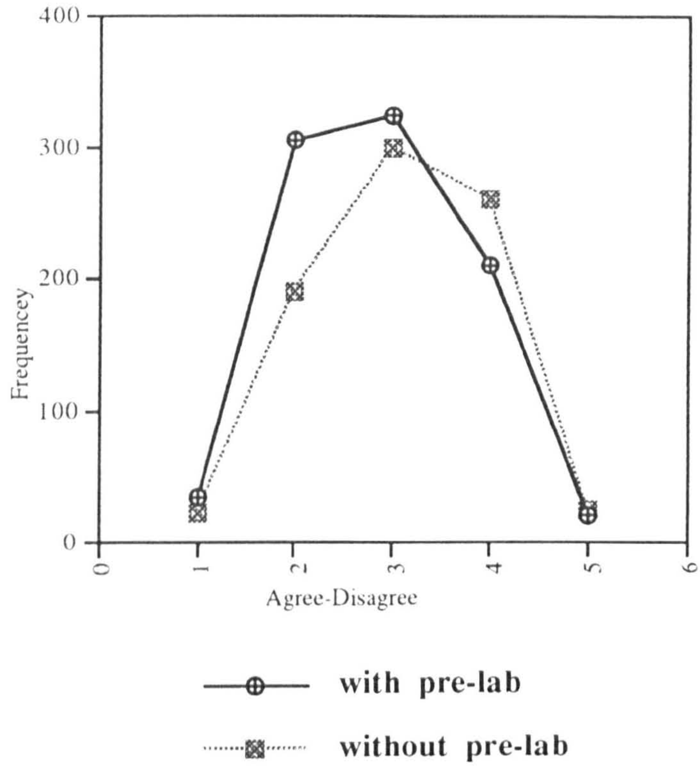
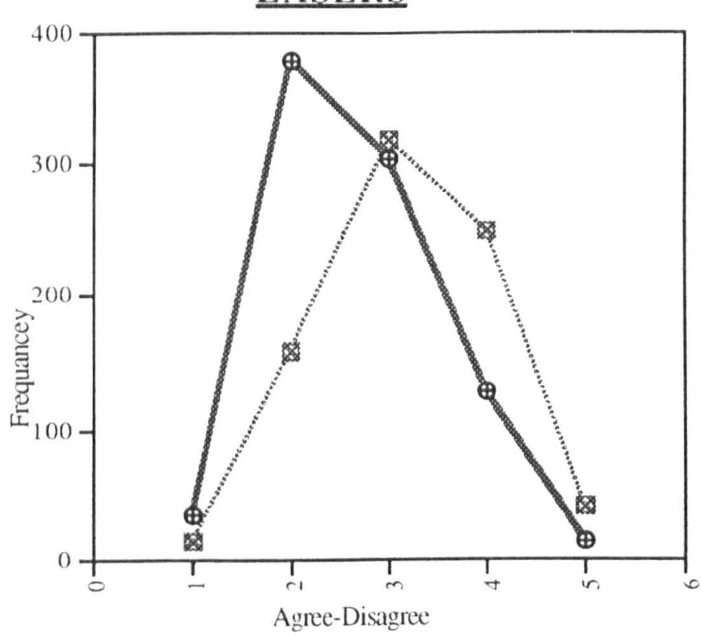
Frequancey
0
1
2
3
4
5
6
Agree-Disagree

MICHELSON INTERFEROMETER



LASERS



6.2.3 FIELD-DEPENDENCE/INDEPENDENCE

It was explained in chapter five that towards the end of second term of phase-I, academic session 1994-95, to separate the sample into groups, the **SHAPES**, Hidden Figure Test (HFT) was administered. The resulting separation is shown in table 6.8.

Table 6.8
FIELD-DEPENDENT/INDEPENDENT

Field Dependent	Field Independent
34	33

Having classified the sample into groups according to their cognitive styles, it is necessary to follow them in their attitude to Physics-II lab. Therefore sample data was also divided in to three parts according to the students' cognitive style of learning, field-dependence/independence.

It should enable us to have a deeper understanding of the nature of attitudes of each group in its cognitive style. The final product of such work may assist physics educators to place emphasis upon the needs of undergraduate students in physics-II laboratory learning.

Moreover, these results may remind and stimulate the thinking of physics educators about what kinds of teaching methods are essential to develop student's ability, and of the degree of attention which should be given to different groups of students in their physics-II learning processes.

The responses were analysed categorically i.e. field-dependent and field-independent groups. Field-intermediate group was not taken into consideration for statistical presentation, since it was the area of separation between the two extremes to remove potential overlap between the field-dependent and field-independent categories.

6.2.3.1 FIELD-DEPENDENTS

There were thirty four field-dependent students in the sample of attitude-phase, during academic session 1994-5 (table 6.8).

Now the researcher will present the statistical picture of these students' responses to the attitude-questionnaire, for each experiment separately in the tables, using the chi-square test on the following pages.

Table 6.9

EXPERIMENT : MICHELSON INTERFEROMETER (N AND O)
34 FIELD-DEPENDENT STUDENTS

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	0	18	13	1	0	
O	0	6	9	9	0	
2.N	1	17	10	4	0	
O	0	6	5	12	1	
3.N	0	19	10	3	0	
O	0	10	6	5	3	
4.N	0	12	17	2	1	
O	0	7	11	6	0	
5.N	0	17	10	5	0	
O	0	2	14	8	0	
6.N	0	12	8	12	0	
O	1	6	10	5	2	
7.N	3	13	8	8	0	
O	1	8	11	4	0	
8.N	5	24	3	0	0	
O	3	14	5	2	0	
9.N	0	16	15	1	0	
O	0	5	15	4	0	
10.N	0	11	11	9	1	
O	0	7	9	7	1	

The above table indicated that some of the values in the cells are less than 5. According to chi-square rule, it is unwise to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results again in some of the values in the cells being less than 5. Therefore we are not applying chi-square test for each individual item, of the field-dependent students' responses for this particular experiment. However we will consider the sum of overall responses from strongly agree to strongly disagree to determine the significance difference between (N) with and (O) without pre-lab groups for the Michelson Interferometer experiment. It is shown in the following table.

TABLE 6.9 (a)

MICHELSON INTERFEROMETER	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	9	159	105	45	2*
Without Pre-Lab (O)	5	71	95	62	7

Again one cell in the table appears with star, represents the value less then 5. Therefore it is doubtful to consider the results as having 4 degrees of freedom. The "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results the following table with degree of freedom 2.

TABLE 6.9 (b)

MICHELSON INTERFEROMETER	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)		168	105	47	
Without Pre-Lab (O)		76	95	69	

The calculated value of the above table is, χ^2=28.514, with degree of freedom = 2. Since the calculated value of χ^2 is greater than the tabulated value, χ^2= 9.21 at 1% level and χ^2= 5.99 at 5% level of significance. This confirms that there is significant difference between the over all students' responses, with pre-lab (N) and without pre-lab (O) for the Michelson Interferometer experiment in favour of pre-lab.

Table 6.10
EXPERIMENT: X-RAYS (N AND O)
34 FIELD-DEPENDENT STUDENTS

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	7	18	2	5	0	
O	1	10	9	2	0	
2.N	1	17	7	1	0	
O	1	10	2	9	0	
3.N	5	19	2	0	0	
O	1	15	5	1	3	
4.N	0	8	16	2	0	
O	0	7	12	3	0	
5.N	0	14	11	1	0	
O	0	6	12	4	0	
6.N	0	10	7	9	0	
O	0	6	12	4	0	
7.N	1	5	16	4	0	
O	0	5	14	3	0	
8.N	11	15	0	0	0	
O	4	12	3	2	1	
9.N	1	8	15	2	0	
O	1	6	14	1	0	
10.N	1	5	11	8	1	
O	0	5	8	9	0	

The above table indicated that some of the values in the cells are less than 5. Therefore we will consider the sum of all the columns from strongly agree to strongly disagree responses for the experiment X-rays, (N)with and (O)without pre-lab and determine the significance of the differences, It is shown in the table 6.10 (a) on the following page.

TABLE 6.10 (a)

X-RAYS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	27	119	86	27	1*
Without Pre-Lab (O)	8	82	91	38	1*

Again the above table indicated that some of the values in two cells having stars are less than 5. According to chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results the following table.

TABLE 6.10 (b)

X-RAYS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)		146	86	28	
Without Pre-Lab (O)		90	91	39	

The calculated value of the above table is, χ^2=11.985, with degree of freedom = 2. Since the calculated value of χ^2 is greater than the tabulated value, χ^2= 9.21 at the 1% level and χ^2= 5.99 at 5% level of significance with 2 degrees of freedom. This confirms that there is positive significant difference between the over all field-dependent students' responses of with pre-lab (N) and without pre-lab (O) for X-rays experiment.

Table 6.11
EXPERIMENT: RESONANCE (N AND O)
34 FIELD-DEPENDENT STUDENTS

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	2	18	12	4	0	
O	0	7	6	7	4	
2.N	1	17	11	7	0	
O	1	5	7	9	2	
3.N	2	21	9	4	0	
O	0	4	5	12	3	
4.N	3	9	18	6	0	
O	0	6	10	7	1	
5.N	0	16	16	4	0	
O	0	2	5	15	1	
6.N	0	12	12	21	1	
O	0	11	4	9	0	
7.N	0	15	12	9	0	
O	0	7	12	5	0	
8.N	3	18	6	7	2	
O	0	12	10	2	0	
9.N	0	12	23	1	0	
O	0	2	12	9	1	
10.N	0	10	12	13	1	
O	1	8	8	7	0	

The table indicated, some of the values in the cells are less than 5. There fore we will consider the sum of all the columns from strongly agree to strongly disagree responses for the experiment Resonance and determine the significant difference. This is shown in the table 6.11(a) on the following page.

TABLE 6.11 (a)

RESONANCE	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	11	148	131	76	4*
Without Pre-Lab (O)	2*	64	79	82	12

The above table indicated, some of the values with stars in two cells are less than 5. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results in the following table, with 2 degree of freedom.

TABLE 6.11 (b)

RESONANCE	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)		159	131	80	
Without Pre-Lab (O)		66	79	94	

The calculated value of the above table is, χ^2=25.441, with degree of freedom = 2. Since the calculated value of χ^2 is greater than the tabulated value, χ^2= 9.21 at the 1% level and χ^2= 5.99 at 5% level of significance with degree of freedom 2. This confirms that there is positive significant difference between the over all field-dependent students' responses of with pre-lab (N) and without pre-lab (O) for the experiment Resonance in favour of pre-lab.

Table 6.12
LASERS (N AND O)
34 FIELD-DEPENDENT STUDENTS

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	0	11	9	6	0	
O	0	1	11	12	2	
2.N	1	12	9	4	0	
O	0	2	12	10	2	
3.N	1	16	7	2	0	
O	0	12	11	3	0	
4.N	0	11	10	5	0	
O	0	9	14	1	2	
5.N	0	11	13	2	0	
O	0	3	9	12	2	
6.N	0	10	7	9	0	
O	1	9	8	8	0	
7.N	1	7	12	5	1	
O	0	5	17	4	0	
8.N	2	15	3	4	2	
O	1	10	4	10	1	
9.N	0	9	12	3	2	
O	0	4	15	7	0	
10.N	0	8	9	8	1	
O	0	7	12	7	0	

The table indicated that some of the values in the cells are less than 5. According to the chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. Again the results appear, some of which have the cells less than 5, there fore chi-square test cannot apply for individual items. We will consider sum of all the columns from strongly agree to strongly disagree responses of the experiment Resonance, (N)with and (O)without pre-lab to determine the significant difference. It is shown in the following table.

TABLE 6.12 (a)

LASERS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	5	110	91	48	6
Without Pre-Lab (O)	2*	62	113	74	9

In the above table, one cell contains star, the value less than 5. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results in the following table, with 2 degree of freedom.

TABLE 6.12 (b)

LASERS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)		115	91	54	
Without Pre-Lab (O)		64	113	83	

The calculated value of the above table is, x^2=23.042, with degree of freedom = 2. Since the calculated value of x^2 is greater than the tabulated value, x^2= 9.21 at the 1% level. This confirms that there is positive significant difference between the over all field-dependent students' responses, with pre-lab (N) and without pre-lab (O) for the experiment Lasers in favour of pre-lab.

Now the researcher intended to consider sum of all the responses, of four experiments to determine the over all attitude of field-dependent students' (N) with pre-lab and (O) with out pre-lab groups.

Table 6.13

SUM RESPONSES OF ALL THE FOUR EXPERIMENTS (N AND O) 34 FIELD-DEPENDENT STUDENTS

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	9	65	35	11	0	
O	1	25	36	30	6	
2.N	4	63	37	16	0	
O	2	25	26	40	5	
3.N	8	75	28	9	0	
O	1	41	29	21	6	
4.N	3	40	61	15	1	
O	0	30	48	17	3	
5.N	0	58	50	12	0	
O	0	13	42	39	3	
6.N	0	35	34	51	0	
O	2	33	34	27	2	
7.N	5	40	48	25	2	
O	1	26	54	17	0	
8.N	21	72	12	11	4	
O	8	50	22	16	2	
9.N	1	45	65	7	2	
O	1	17	58	21	0	
10.N	1	34	43	39	3	
O	1	27	38	31	1	

The above table indicated that some of the values in the cells are less than 5. According to the chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results the following table with degree of freedom 2.

Table 6.13 (a)

Q: Nos.	A	N	D.A	CHI-SQUARE Tabulated value At 5%LOS=5.99 And At 1%LOS=9.21, df=2
1.N	74	35	11	
O	26	36	36	34.483>T.V
2.N	67	37	16	
O	27	26	40	30.823>T.V
3.N	83	28	9	
O	42	29	27	20.454>T.V
4.N	43	61	16	
O	30	48	20	2.111*&<T.V
5.N	58	50	12	
O	13	42	42	43.939>T.V
6.N	35	34	51	
O	35	34	29	3.869*<T.V
7.N	45	48	27	
O	27	54	17	4.957*<T.V
8.N	93	12	15	
O	58	22	18	9.200>T.V
9.N	46	65	9	
O	18	58	22	16.043>T.V
10.N	35	43	42	
O	28	38	31	.220*<T.V

The above table indicated that there is no significant difference between **O** and **N** students' responses of item numbers four (measuring the interest), six (measuring ease), seven (represents understanding to the relevant course/topics), and ten (measuring application of knowledge). However the calculated values of other items are greater than the tabulated values, and there is significant difference between with pre-lab and without pre-lab responses. It is an indication of a change in field-dependent students' attitude while they perform experiments with pre-lab.

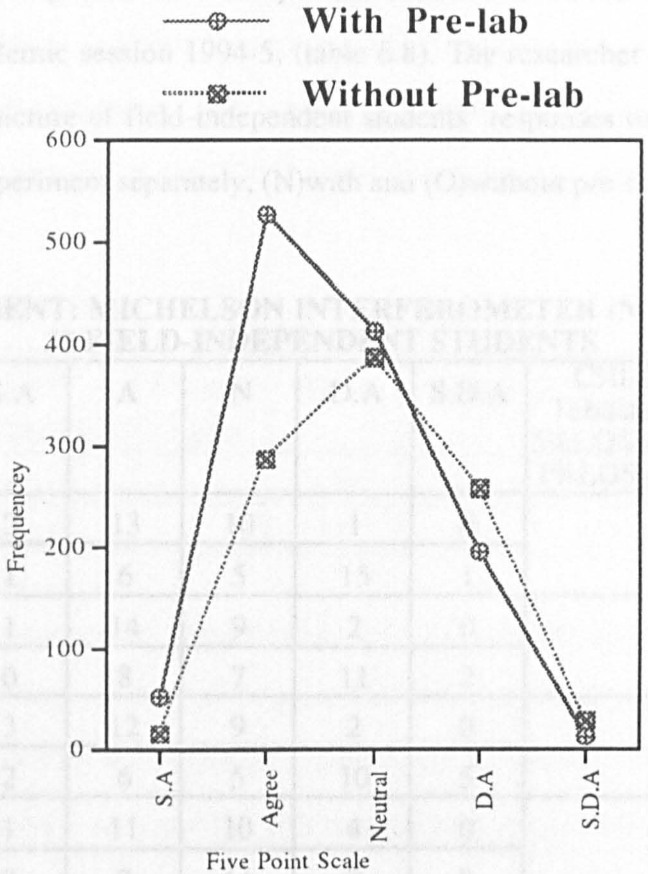
Now we will consider the sum of all the responses in the columns from strongly agree to strongly disagree, to confirm the field-dependent students' attitude to the over all physics-II laboratory work, with pre-lab (N) and without pre-lab (O) groups. This is shown in the following table.

TABLE 6.13 (b)

SUM FOUR EXPERIMENTS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	52	527	413	196	13
Without Pre-Lab (O)	17	287	387	259	29

The calculated value of the above table is, χ^2=82.426, with degree of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, χ^2= 13.28 at the 1% level. This confirms that there is high significant difference between the over all field-dependent students' responses, with pre-lab (N) and without pre-lab (O) in the positive direction. Thus we conclude that pre-lab improved the field-dependent students' attitude to physics-II laboratory work.

FIELD-DEPENDENT, 34 STUDENT



6.2.3.2 FIELD-INDEPENDENTS

There are thirty three field-independent students in the sample, during the attitude phase, academic session 1994-5, (table 6.8). The researcher intended to present the statistical picture of field-independent students' responses to attitude-questionnaire, for each experiment separately, (N)with and (O)without pre-lab, using chi-square test.

Table 6.14

EXPERIMENT: MICHELSON INTERFEROMETER (N AND O)
33 FIELD-INDEPENDENT STUDENTS

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	2	13	10	1	0	
O	1	6	5	15	1	
2.N	1	14	9	2	0	
O	0	8	7	11	2	
3.N	3	12	9	2	0	
O	2	6	5	10	5	
4.N	1	11	10	4	0	
O	0	7	14	7	0	
5.N	0	15	8	3	0	
O	0	8	6	13	1	
6.N	0	9	9	8	0	
O	1	8	7	10	2	
7.N	1	11	7	6	0	
O	1	10	14	3	0	
8.N	8	16	0	1	2	
O	5	9	5	7	2	
9.N	0	10	15	0	0	
O	0	5	14	9	0	
10.N	0	7	12	6	1	
O	0	7	12	9	0	

The table 6.14 indicated that some of the values in the cells are less than 5. According to chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore as before the results were reduced to two degrees of freedom by combination. The "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results the following table with 2 degrees of freedom.

Table 6.14 (a)

MICHELSON INTERFEROMETER	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)		134	89	36	
Without Pre-Lab (O)		84	89	107	

The calculated value of the above table is, $\chi^2 = 43.689$, with degree of freedom = 2. Since the calculated value of χ^2 is greater than the tabulated value, $\chi^2 = 9.21$ at 1% level. This confirms that there is a significant difference between the over all students' responses, with pre-lab (N) and without pre-lab (O) for the Michelson Interferometer experiment in positive direction.

Table 6.15
EXPERIMENT: X-RAYS (N AND O)
33 FIELD-INDEPENDENT STUDENT

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	5	32	9	0	0	
O	1	13	3	0	1	
2.N	2	25	16	3	0	
O	2	6	4	4	2	
3.N	7	32	4	3	0	
O	1	11	5	1	0	
4.N	0	16	25	5	0	
O	1	4	10	3	0	
5.N	2	23	17	4	0	
O	0	6	8	3	1	
6.N	0	18	13	12	3	
O	1	7	3	7	0	
7.N	1	10	27	7	1	
O	0	3	12	3	0	
8.N	14	29	2	0	1	
O	4	7	4	2	1	
9.N	1	15	26	3	1	
O	0	5	11	1	1	
10.N	1	10	16	17	2	
O	0	5	8	5	0	

The above table indicate that some of the values in the cells are less than 5. According to chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results in the following table. Still some of the values in the cells are less then 5, therefore we will consider sum of all the columns from strongly agree to strongly disagree responses for the experiment X-rays, (N)with and (O)without pre-lab and determine the significance difference, It is shown in the following table.

TABLE 6.15 (a)

X-RAYS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	33	210	155	54	7
Without Pre-Lab (O)	10	67	68	29	6

The calculated value of the above table is, χ^2=7.237, with degree of freedom = 4. Since the calculated value of χ^2 is less than the tabulated value, χ^2= 13.28 at the 1% level and χ^2= 9.49 at the 5% level of significance. This confirms that there is no significant difference between the over all field-independent students' responses of with pre-lab (N) and without pre-lab (O) for X-rays experiment.

No significant change found in the attitude of field-independent students for the experiment X-rays. While they responded having had pre-lab for this experiment. Looking again at the pre-lab sheet, it is evident that it does not address any particular difficult concepts or procedure. We conclude that the information in the lab manual is equally satisfactory as the information presented in the pre-lab, for this particular group (field-independent). OR it can be said that since the field-independent students picked the maximum signals from the lab manual as well as from the pre-lab and find no big difference between both the informations. Therefore the responses reflects no significant change in the attitude of field-independent students for the X-rays experiment.

Table 6.16

EXPERIMENT: RESONANCE (N AND O)
33 FIELD-INDEPENDENT STUDENT

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	0	14	8	3	1	
O	1	4	11	6	6	
2.N	12	7	7	0	0	
O	0	8	6	12	2	
3.N	0	14	9	3	0	
O	2	6	12	4	4	
4.N	0	8	12	6	0	
O	1	7	17	2	1	
5.N	0	8	13	5	0	
O	0	8	11	8	1	
6.N	0	9	10	7	0	
O	2	8	6	11	1	
7.N	0	9	13	3	1	
O	1	10	10	6	1	
8.N	1	11	5	9	0	
O	2	17	6	3	0	
9.N	0	5	18	3	0	
O	1	5	15	7	0	
10.N	0	3	12	11	0	
O	1	6	13	6	2	

The above table indicated that some of the values in the cells are less than 5. It is doubtful to consider the results as having 4 degrees of freedom. Therefore same procedure was followed as we did for the last table. This results in the table 6.16 (a) on the following page, with 2 degree of freedom.

Table 6.16 (a)

RESONANCE	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)		94	107	59	
Without Pre-Lab (O)		90	107	83	

The calculated value of the above table is, χ^2=3.407, with degree of freedom = 2. Since the calculated value of χ^2 is less than the tabulated value, χ^2= 9.21 at the 1% level. This confirms that there is no significant difference between the over all field-independent students' responses of with pre-lab (N) and without pre-lab (O) for the experiment Resonance .

Table 6.17
EXPERIMENT: LASERS (N AND O)
33 FIELD-INDEPENDENT STUDENT

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	0	16	6	4	2	
O	0	4	8	14	2	
2.N	0	18	5	4	1	
O	2	8	12	6	0	
3.N	2	17	7	1	1	
O	1	8	7	11	1	
4.N	1	10	14	1	2	
O	1	7	12	6	2	
5.N	1	10	10	7	0	
O	0	5	11	12	0	
6.N	0	11	6	11	0	
O	1	8	12	7	0	
7.N	0	13	7	8	0	
O	1	6	12	7	2	
8.N	2	18	1	6	1	
O	0	8	11	8	1	
9.N	0	6	16	5	1	
O	0	5	18	5	0	
10.N	1	8	10	9	0	
O	1	7	12	8	0	

The above table indicated that some of the values in the cells are less than 5. According to the chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. Again the result appear, some of the values in the cells less then 5, there fore we will consider sum of all the columns from strongly agree to strongly disagree responses for the experiment Resonance (N)with and (O)without pre-lab and determine the significance difference, as shown in the following table.

TABLE 6.17 (a)

LASERS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	7	127	82	56	8
Without Pre-Lab (O)	7	66	115	84	8

The calculated value of the above table is, χ^2=30.408, with degree of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, χ^2= 13.28 at the 1% level. This confirms that there is positive significant difference between the over all field-independent students' responses, with pre-lab (N) and without pre-lab (O) for the experiment Lasers.

Now the researcher intended to consider sum of all the responses, of four experiments to determine the over all attitude of field-independent students' (N) with pre-lab and (O) with out pre-lab groups. This is presented in the table 6.18 on the following page.

Table 6.18
SUM RESPONSES OF ALL THE FOUR EXPERIMENTS(N AND O) 33 FIELD-INDEPENDENT STUDENT

Q: Nos.	S.A	A	N	D.A	S.D.A	CHI-SQUARE Tabulated value At 5%LOS=9.49 And At 1%LOS=13.28, df=4
1.N	7	75	33	8	3	
O	3	27	27	35	10	
2.N	3	69	37	16	1	
O	4	30	29	33	6	
3.N	12	75	29	9	1	
O	6	31	29	26	10	
4.N	2	45	61	16	2	
O	3	25	53	18	3	
5.N	3	56	48	19	0	
O	0	27	36	36	3	
6.N	0	47	38	38	3	
O	5	31	28	35	3	
7.N	3	43	54	24	2	
O	3	29	48	19	3	
8.N	25	74	8	16	3	
O	11	41	26	20	4	
9.N	2	36	75	11	2	
O	1	20	58	22	1	
10.N	2	28	50	43	3	
O	2	25	45	28	2	

The above table indicated that some of the values in the cells are less than 5. According to the chi-square rule, it is doubtful to consider the results as having 4 degrees of freedom. Therefore the "disagree" and "strongly disagree" replies are combined, as are the "agree" and "strongly agree. This results the following table with degree of freedom 2.

Table 6.18 (a)

Q: Nos.	A	N	D.A	CHI-SQUARE Tabulated value At 5%LOS=5.99 And At 1%LOS=9.21, df=2
1.N	82	33	11	
O	30	27	45	34.483>T.V
2.N	72	37	17	
O	34	29	39	20.941>T.V
3.N	87	29	10	
O	37	29	36	32.693>T.V
4.N	47	61	18	
O	28	53	22	3.500*<T.V
5.N	59	48	19	
O	27	36	39	18.193>T.V
6.N	47	38	41	
O	36	28	38	.567*<T.V
7.N	46	54	26	
O	32	48	22	.680*<T.V
8.N	99	8	19	
O	52	26	24	22.463>T.V
9.N	38	75	13	
O	21	58	23	7.405>T.V
10.N	30	50	46	
O	27	45	30	14.552>T.V

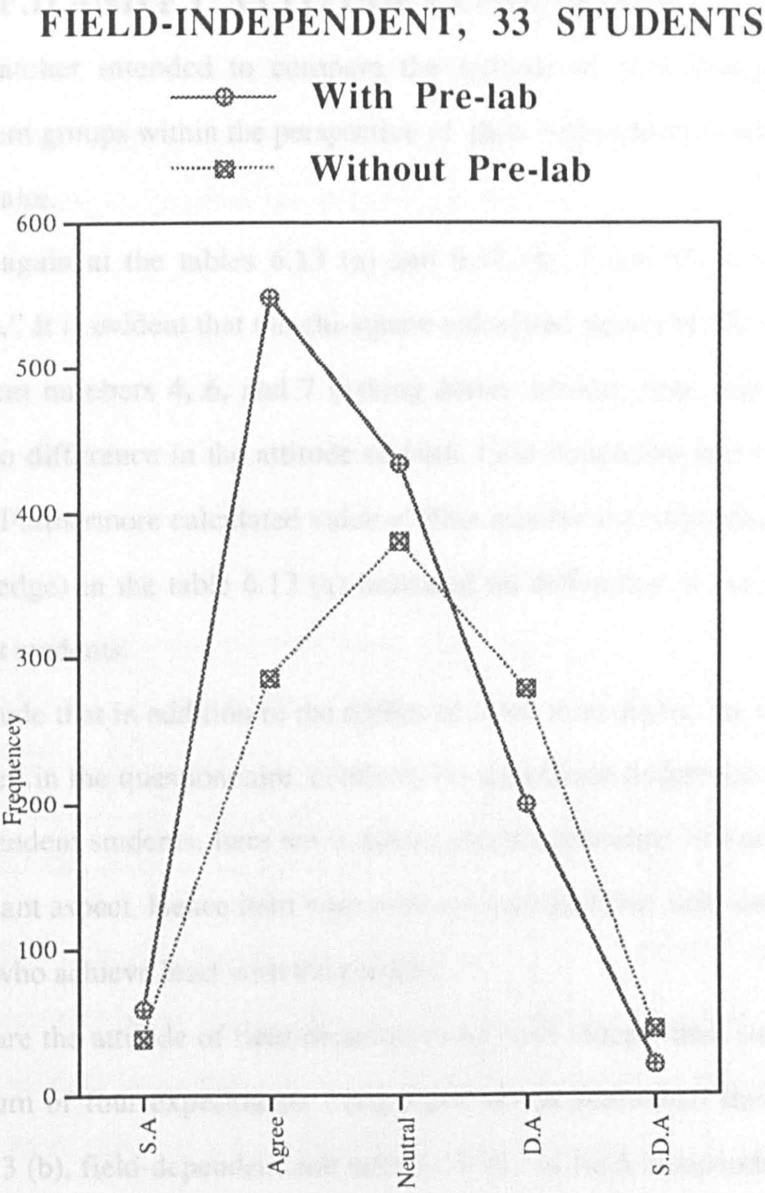
The above table indicated that there is no significant difference between **O** and **N** students' responses of calculated values having stars on TV, that is item numbers four (measuring interest), six (measuring ease), and seven (represent understanding to the relevant course/topics). However the calculated values of all other items are greater than the tabulated values. There is a significant difference between with pre-lab and without pre-lab responses. It is an indication of a change in field-independent students' attitude while they perform experiments with pre-lab.

Now we will consider sum of all the responses in the columns from strongly agree to strongly disagree. To confirm the field-independent students' attitude to the over all physics-II laboratory work, with pre-lab (N) and without pre-lab (O) groups. This is shown in the following table.

TABLE 6.18 (b)

SUM FOUR EXPERIMENTS	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
With Pre-Lab (N)	59	548	433	200	20
Without Pre-Lab (O)	38	286	379	279	45

The calculated value of the above table is, χ^2=86.741, with degree of freedom = 4. Since the calculated value of χ^2 is greater than the tabulated value, χ^2= 13.28 at the 1% level and χ^2= 9.49 at 5% level of significance. This confirms that there is high significant difference between the over all field-independent students' responses, with pre-lab (N) and without pre-lab (O) in the positive direction. We conclude that pre-lab has fostered the attitude of field-independent students to physics-II laboratory work.


FIELD-INDEPENDENT, 33 STUDENTS
With Pre-lab
Without Pre-lab
600
500
400
300
200
100
0
Frequencey
S.A
Agree
Neutral
D.A
S.D.A
Five Point Scale

6.2.3.3 F.D AND F.I ATTITUDE COMPARISON

The researcher intended to compare the attitude of field-dependent and field-independent groups within the perspective of their replies to each item in the attitude-questionnaire.

Looking again at the tables 6.13 (a) and 6.18 (a), "sum of all four experiments responses." It is evident that the chi-square calculated values of the "three" questions that is item numbers 4, 6, and 7 (asking about interest, ease, and understanding), reflects no difference in the attitude of both, field-dependent and field-independent students. Furthermore calculated value of item number ten (regarding the application of knowledge) in the table 6.13 (a) indicated no difference in the attitude of field-dependent students.

We conclude that in addition to the replies of other three items, the responses to item number ten in the questionnaire, confirms no significant difference in the attitude of field-dependent students. Item ten is asking about application of knowledge which is an important aspect. Hence item wise analysis indicated that field-dependent students are ones who achieve least with the pre-labs.

To compare the attitude of field-dependent and field-independent students within the overall sum of four experiments irrespective of the individual items. Consider the tables 6.13 (b), field-dependent and table 6.18 (b), of field-independent students. It is evident that the chi-square calculated values are significant in both the cases, but the significance values of field-independent (86.741) is higher then the significance value of field-dependent (82.426) group of students. This suggests that the field-dependent students with pre-lab benefited less than the field-independent students, in the sample during phase-I.

6.3 LABORATORY RESULT

The demonstrators were responsible for assessing the students' performance in the particular experiments as a whole including different aspects such as writing, calculating handling etc. against the set criteria that is maximum ten marks for each experiment.

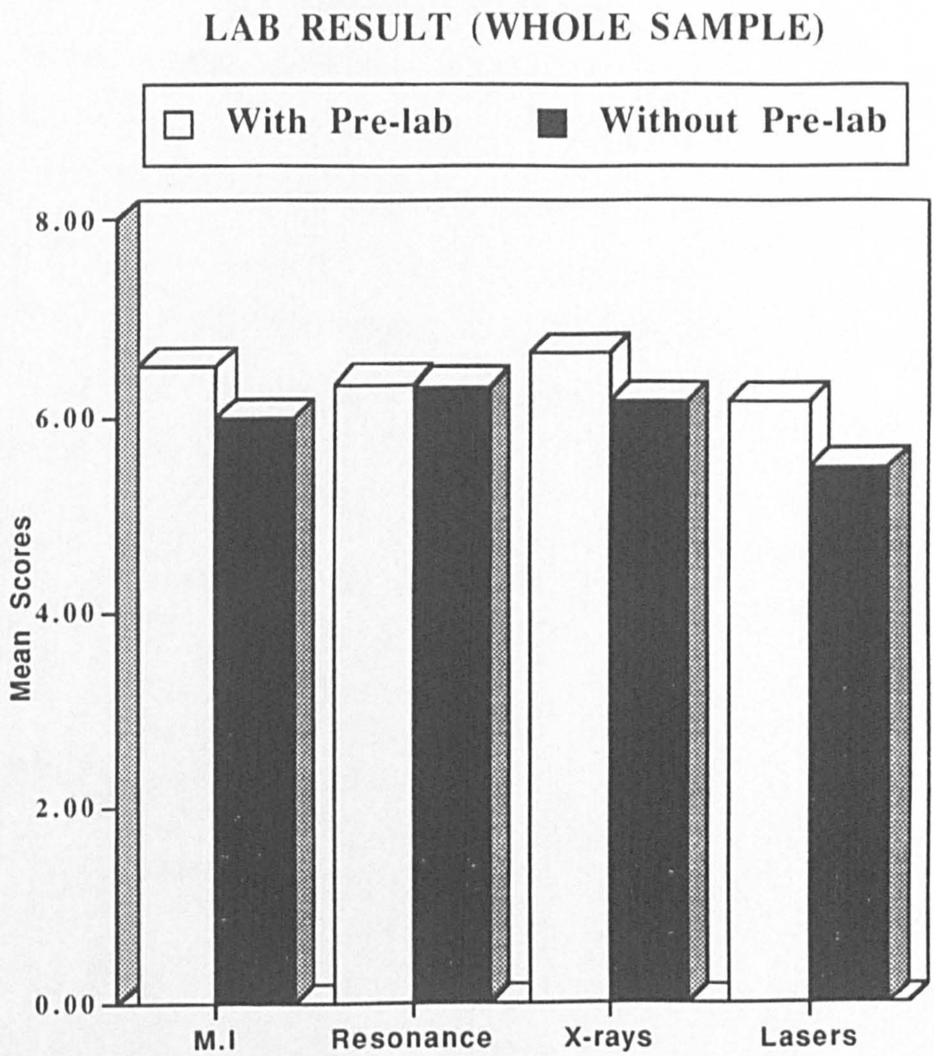
The scores made by the whole sample irrespective of the students' cognitive learning style in each experiment, during phase-I, with pre-lab and with out pre-lab procedure employed for this study have been analysed and are presented here in the following tables.

TABLE 6.19
SUM OF ALL FOUR EXPERIMENTS (Mean Scores)

Sum Of All Four Experiments	M. Inter-ferometer	Resonance	X-rays	Laser
With Pre-Lab	6.51	6.33	6.65	6.14
Without Pre-Lab	5.98	6.30	6.36	5.50

The above table indicated that the students' performance in their experiments with pre-lab is marginally better than without pre-lab. The mean scores made by with pre-lab group are slightly better than the mean scores made by without pre-lab group.

It is evident from this that pre-lab helped the students marginally to improve the students understanding to physics-II laboratory work which may support, what was predicted by the hypothesis (2).



It is apparent from the comparison of above columns that the students' performance with pre-lab is better than without pre-lab laboratory work. From this it is evident that the pre-lab helped to improve the students' understanding of laboratory work. Which may support what was predicted in the hypothesis-2 that is "pre-lab can help to improve the students' understanding of physics-II practical work".

6.3.1 FIELD-DEPENDENCE/INDEPENDENCE

Now we will consider the sample students' performance with in their cognitive styles of learning i.e. field-dependence/field-independence.

As it is shown in section 6.2.3 the sample was divided into its groups, according to the cognitive style of learning that is thirty four students are field-dependent and thirty three students appeared field-independent. While twenty eight students were found field-intermediate, the data of which is not considered for statistical analysis as it is an intermediate group.

The picture which emerged from the mean scores of the practical work for each experiment with pre-lab and with out pre-lab of the groups is presented in the following table.

Table 6.20
MEAN SCORES (With And Without Pre-lab)

	FIELD INDEPENDENT		FIELD DEPENDENT	
Experiments	With Pre-Lab	Without Pre-Lab	With Pre-Lab	Without Pre-Lab
M. Interferometer	8.04	6.55	6.96	5.10
Resonance	8.12	6.82	6.44	5.21
Lasers	7.16	6.32	5.81	4.67
X-rays	7.46	7.02	6.45	6.37
Average Lab Mean	7.71	6.73	6.39	5.51

The results of the above table indicated that the students' performance in their experiments with pre-lab is better then without pre-lab (hypothesis-2). The mean scores of field-independent students are better than field-dependent students (hypothesis-3). Field-independent students with pre-lab perform better then without pre-lab (hypothesis-4). Field-dependent students with pre-lab perform better then without pre-lab (hypothesis-5). Field-dependent students with pre-lab did not perform better than field independent without pre-lab (hypothesis-6). Thus it is evident from this that pre-lab helped the students to improve their understanding of physics-II laboratory work and the field-independent learners in this sample perform better in Physics-II lab then field-dependent which may support, what was predicted by the hypotheses nos. 2-5.

6.4. OVER ALL PHYSICS-II RESULT

Now we will consider overall Physics-II course, by parts and evaluate the sample students' performance, irrespective of with and without pre-lab groups, but within their cognitive learning style. The mean scores of the sample in different parts of physics-II course, are presented in the following table.

Table 6.21

MEAN SCORES

Parts Of Physics-II Course	Field-dependent	Field-independent
Class Marks (March)	44.30	53.00
Class Marks (December)	49.52	55.64
Average Class Marks	48.94	53.17
Michelson Interferometer	5.87	7.14
Lasers	5.21	6.73
Resonance	5.82	7.45
X-rays	6.40	7.24
Sum Lab	23.29	28.56
Library Project	7.50	7.81
Free Range Experiment	9.66	11.00
Degree Exam	55.29	60.10

The result of the table 6.21 indicate that the mean scores of field-independent students are better than field-dependent students in all of the physics-II aspects. It is evident from this, that field-independent learners in this sample performed better in the physics-II course than field-dependent learners which may support, what was predicted by the hypothesis; that is, the overall performance of field-independent students would be better than field-dependent in the physics-II course.

6.5 SUMMARY

The attitude and performance of the sample is reflected in this chapter. The attitude phase extended over two terms of academic session 1994-95.

Results and data analysis is presented in three steps that is: (1) Attitude questionnaire result, (2) Laboratory result and (3) Over all physics-II course result.

Phase-I is deeply concerned with sample students' attitude, towards the changes made in physics-II laboratory procedure.

The attitude of field-independent students has not changed significantly in favour of pre-lab, for the particular result of the experiment X-rays. In general, it seems that the results give supports, to what was predicted by the hypotheses, raised in chapter 5.

To sum up, the result which emerged from the study of the students' responses to the attitude questionnaire, tend to confirm that pre-lab fostered a positive attitude in the students, towards the changes made in physics-II lab irrespective of their cognitive style of learning. Moreover the attitude of both field-dependent and field-independent students was foundto be positive to the pre-labs, but the calculated significance values revealed that the attitude of field-independent students changed more positively than the attitude of field-dependent students.

Laboratory results indicated that pre-lab helped the students to improve their understanding of physics-II practical work. Field-independent students with pre-lab perform better then field-dependent with pre-lab work and field-independent without pre-lab performed better then field-dependent without pre-lab students in physics-II practical work.

The over all physics-II course result indicated that field-independent students are better than field-dependent in physics-II course.

CHAPTER SEVEN

RESULTS AND DISCUSSION (PHASE-II)

7.1 INTRODUCTION

The second practical part of this study involves attempting to find out about **Cognition**, i.e. students' understanding, of physics-II practical work related to their cognitive style of learning, field-dependence/field-independence and to their pre-lab.

In addition to post-lab scores, the scores made by the students in the Physics-II laboratory parts/sections (experiments, library project, free range experiments), class tests and degree exam are also taken into consideration for statistical procedures.

In this chapter it is intended to test the hypotheses raised in chapter five of this thesis.

The result analysis of the cognition phase are presented here in three major sections. The first section displays **Post-Lab Results,** to explore the student's understanding of physics-II practical work, against pre-lab and without pre-lab procedures and finding the significance of the use of pre-labs. The second part describes the **Laboratory Result** that is the normal score made by the students in their experiments with pre-lab and with out pre-lab methods. The third section extends to the **Over All Physics-II Result** which includes the students' performance in class tests, degree exam, library project and free range experiment.

7.2 POST-LAB RESULT

7.2.1 POST-LAB

During the attitude phase, academic session 1994-95, we investigated the possibility of introducing post-lab work into the physics-II lab. The result was encouraging as the students recognised that this would be likely to make them organise and plan their own strategies to solve the post-lab problems. They also agreed that such exercises should be more frequent.

The post-labs developed in this phase were aimed to assess the students' improved understanding of physics-II practical work as well as to engage the students in the subject, recalling new knowledge, techniques and skills they learned and link the subject to its applications.

The post-lab give the students the opportunity to solve problems using their own strategies, to think independently, to develop skills in solving the problems, and make them draw conclusion from the results.

Post lab problems were prepared, to motivate and develop students' interest in physics, to engage them more and relate the subject to their own experience helping them to develop a better understanding of the subject.

Each post-lab used in this study, had at least seven items associated with the experiment. These items extended over Bloom's cognitive domain.

The table on the following page reflects the shape of post-labs for each experiment, developed to use effectively in physics-II lab during phase-II. Some of the questions test more than one outcome and appear more then once in a column.

Table 7.1
POST-LABS OUT COMES

POST-LABS	X-rays	M.I	Lasers	Resonance
Outcomes	Q:Nos	Q:Nos	Q:Nos	Q:Nos
1. Recall Of Facts	1, 2, 3	6,	1, 3, 6	1, 2
2. Use Of Facts In Familiar Way	4, 5	4, 5, 10	1, 2, 3	
3. Use Of Facts In An Unfamiliar Way	6, 7, 8	1, 2, 3	5, 7	1, 6, 7, 8
4. Analysis & Synthesis	6, 8	2, 3	3, 7	3

For example item number seven in the post-lab of Lasers' experiment was; "Look at the strong source of light (not a laser) through the fabric of your handkerchief, and you will see an unusual pattern. Explain how it arises. What does it tell you about the cloth? Write your explanation". The item covers the application of knowledge (diffraction) in an unfamiliar way (to cloth), analysis and synthesis levels of comprehension. Similarly each item in the post-labs covers some of the aspects of cognitive domain.

7.2.2 ASSESSMENT PROCEDURE

It was described in the methodology that after one week of the completion of each experiment the students were required to do the post-lab work before they started the next experiment. The post-lab sheets were supplied to the students and collected later in the same day. The researcher kept a record of each student in two separate files that is, the post-lab work with pre-lab and the post-lab work without pre-lab. This procedure was followed throughout the two terms, during the whole academic session 1995-96, of the cognition phase. So each student in the sample performed post-lab work for all the four selected experiments (explained in chapter five).

It has already been explained in the time table (chapter five page 104), that pre-lab sheets were supplied to the students one week before the start of the particular experiment, for half of the experiments, and each student did half of his experiments with pre-lab and half without pre-lab. Hence the post-lab sheets collected from each individual student, is of two kinds one with pre-lab and other without pre-lab.

To assess the students' performance in their post-lab work, a set of criteria was made for each post-lab by setting out the maximum marks for each question asked in the post-labs. The maximum marks for a post-lab sheet depends on the experiment and the items present in it. Such as for Michelson Interferometer the maximum score was 19, for X-rays 16, for Lasers 9 and for Resonance 20.

The post-lab work done by the students was marked accordingly, then the score of each question in the post-lab was summed up. To enable easy comparisions between post-labs to be made, all the scores made by the students in each post-lab sheet were converted into percentages separately. These percentage scores were used as the basis of all further analysis.

Many statistical methods are available for estimating significant difference between the two mean scores. We used the t-test for the mean scores employed. The t-test is a convenient way to involve the primary data in determination of significant difference between the two mean score. The formula which we used is reproduced here as under:

$$t = \frac{\overline{X}_1 - \overline{X}_2\sqrt{(N_1 + N_2 - 2)N_1N_2}}{\sqrt{(N_1S_1^2 + N_2S_2^2)(N_1 + N_2)}}$$

In the formula, t = t-test, $\overline{X}_1$= Mean for set one, $\overline{X}_2$= Mean for second set, N_1= Number of students in set one, N_2= Number of students in set two, S_1^2= Variance for set one, S_2^2= Variance for set two.

The picture which emerged from the processed percentage-mean scores, using the methods (with pre-lab/set one and without pre-lab/set two) for each experiment, in the post-lab work is presented in the table 7.1.

Table 7.2
POST-LABS PERCENTAGE-MEAN SCORES (Whole Sample)

POST-LABS SUM OF FOUR EXPERIMENTS	Resonance	Michelson Interferometer	X-rays	Laser
Without pre-lab (O)	33.89	49.32	55.24	58.48
With pre-lab (N)	47.97	59.70	57.43	75.98
t-test at 5% level of significant	4.06>T.V df=71	2.73>T.V df=71	0.54<T.V df=72	4.66>T.V df=73

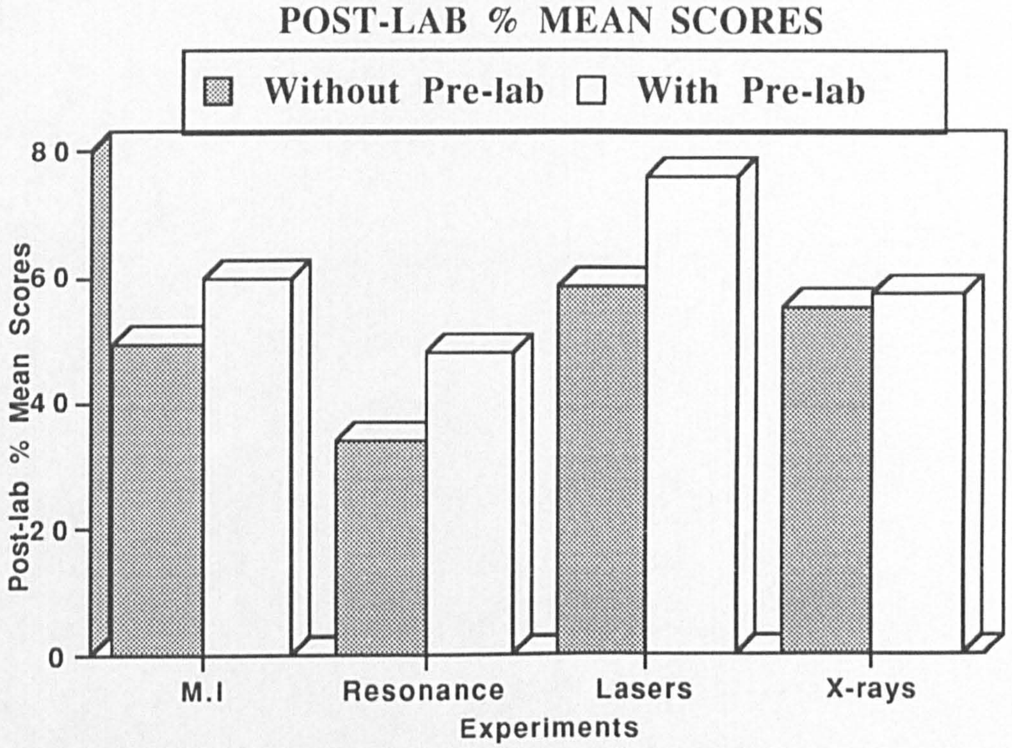
The degrees of freedom are determined by using the formula: df=N_1+N_2-2. Where N_1 and N_2 are the total numbers of students in the set one (with pre-lab) and in the set two (without pre-lab). While T.V = Tabulated value.

The t-test row in the above table indicated that except X-rays, all the calculated values are greater than the tabulated values and there is a significant difference between (N) with pre-lab and (O) without pre-lab mean scores. The students' understanding of physics-II practical work is improved when they performed their experiments Michelson Interferometer, Lasers and Resonance, with pre-lab (N).

No significant difference found between with pre-lab (N) and without pre-lab (O) for the X-rays experiment. Looking again at the X-rays pre-lab sheet, it is evident that it does not address any particularly difficult concepts or procedure. We conclude that the information in the lab manual is equally satisfactory as the information presented in the pre-lab. Therefore the post-lab mean scores reflects no significant change in students' understanding of the experiment X-rays.

However the results in the table also indicated that the post-lab percentage-mean scores with pre-lab are better than those without pre-lab in all the cases including the X-rays post-lab mean scores. It is evident from this that pre-lab helped the students to improve their understanding of the practical work in the physics-II laboratory, which may support what was predicted in the hypothesis (2) that is "Pre-lab can help to improve the students understanding in physics-II practical work".

From the mean scores in the table 7.2, a histogram is presented here, which gives a more clearer picture.



It is apparent from the above columns that the scores made by the students in their post-lab work while they performed the experiments with pre-lab are better than that of the experiments performed without pre-lab, again it confirm that the pre-lab helped the students to improve their understanding of practical work in physics-II laboratory.

7.2.3 FIELD-DEPENDENCE/INDEPENDENCE

Similar to phase-I (Attitude phase), the sample of cognition phase was also observed in to the groups according to the students cognitive style of learning that is the field-dependence/field-independence.

Towards the end of second term of the academic session 1995-96, **SHAPES** the Hidden Figure Test (HFT) was administered to the students sample.

The groups which emerged are presented in the table 7.3 as under:

Table 7.3
FIELD-DEPENDENT AND FIELD-INDEPENDENT

Field-Dependent	Field-Independent
26	28

The researcher intended to analyse the post-lab scores made by the sample students, categorically i.e. field-dependent and field-independent groups. Field-intermediate group was not taken under consideration of statistical presentation, to provide a clear separation between field-dependent and field independent.

The picture which emerged from the % mean scores of the post-lab work with and without pre-labs is presented here separately for each group, in the table 7.4 and 7.5 on the following page.

Table 7.4
FIELD-DEPENDENT POST-LAB % MEAN SCORES
(With And Without Pre-lab)

POST-LAB WITH & WITHOUT PRE-LAB	With Pre-Lab	Without Pre-Lab	t-Test At 5% Level Of Significant
Experiments	C1	C2	
Michelson Interferometer	60.53	44.44	1.97<T.V, df=21
Resonance	47.08	33.75	2.35>T.V, df=22
Laser	71.30	52.46	3.35>T.V, df=24
X-rays	61.00	52.00	1.45<T.V, df=22

The last column in 7.4 table indicated that all the calculated values of t-test are less than the tabulated values (T.V) and there is no significant difference, between (N) with pre-lab and (O) without pre-lab scores except the Lasers experiment. It means that the students' understanding of physics-II practical work is not improved significantly in favour of pre-lab, however clear significant improvement in the understanding of field-dependent students can be seen from the calculated value of the experiment Lasers in favour of those with pre-lab work.

Table 7.5
FIELD-INDEPENDENT POST-LAB % MEAN SCORES
(With And Without Pre-lab)

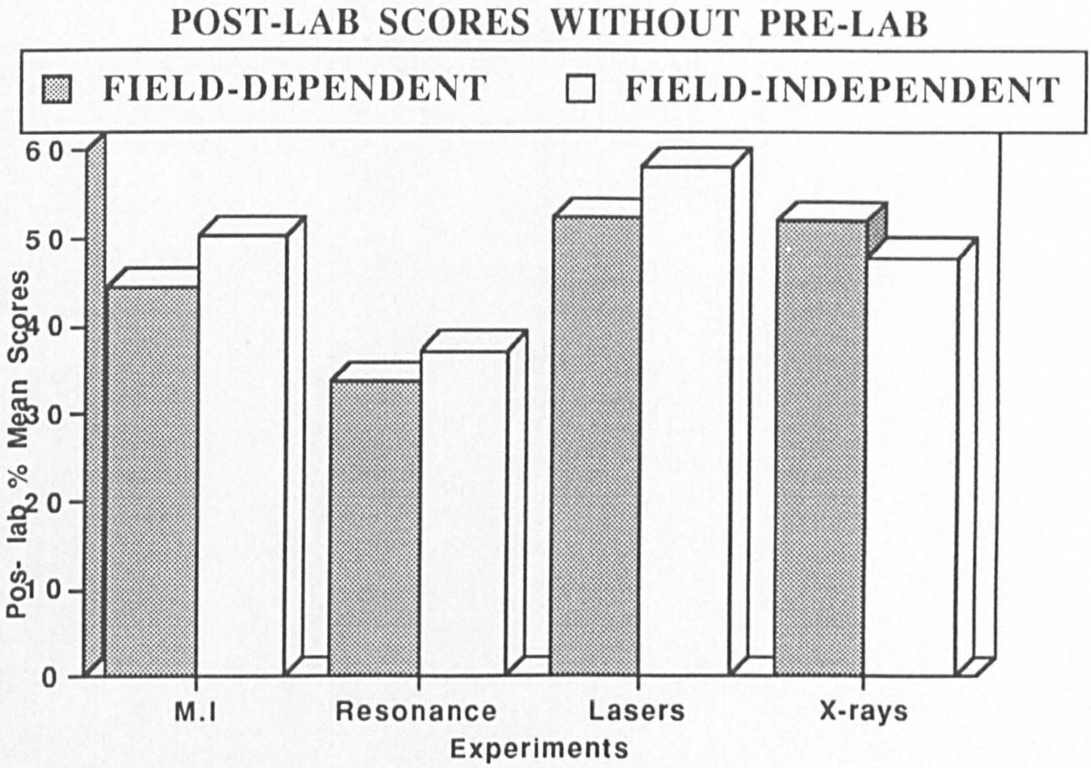
POST-LAB WITH & WITHOUT PRE-LAB	With Pre-Lab	Without Pre-Lab	t-Test At 5% Level Of Significant
Experiments	C3	C4	
Michelson Interferometer	63.56	50.38	2.33>T.V, df=25
Resonance	50.33	37.27	2.45>T.V, df=24
Laser	77.78	58.33	2.89>T.V, df=21
X-rays	62.50	48.00	1.87<T.V, df=25

The above tables 7.5 indicated that apart from X-rays, all the calculated values are greater than the tabulated values of t-test and there is a significant difference between (N) with pre-lab and (O) without pre-lab scores. From this it is evident that the field-independent students' understanding of physics-II practical work is improved significantly when they performed their experiments with pre-lab.

The calculated values of the X-rays experiment show, no significant improvement in the understanding of field-independent students. Looking at the X-rays pre-lab sheet, the pre-lab did not identify any particular difficult point for an improvement in understanding.

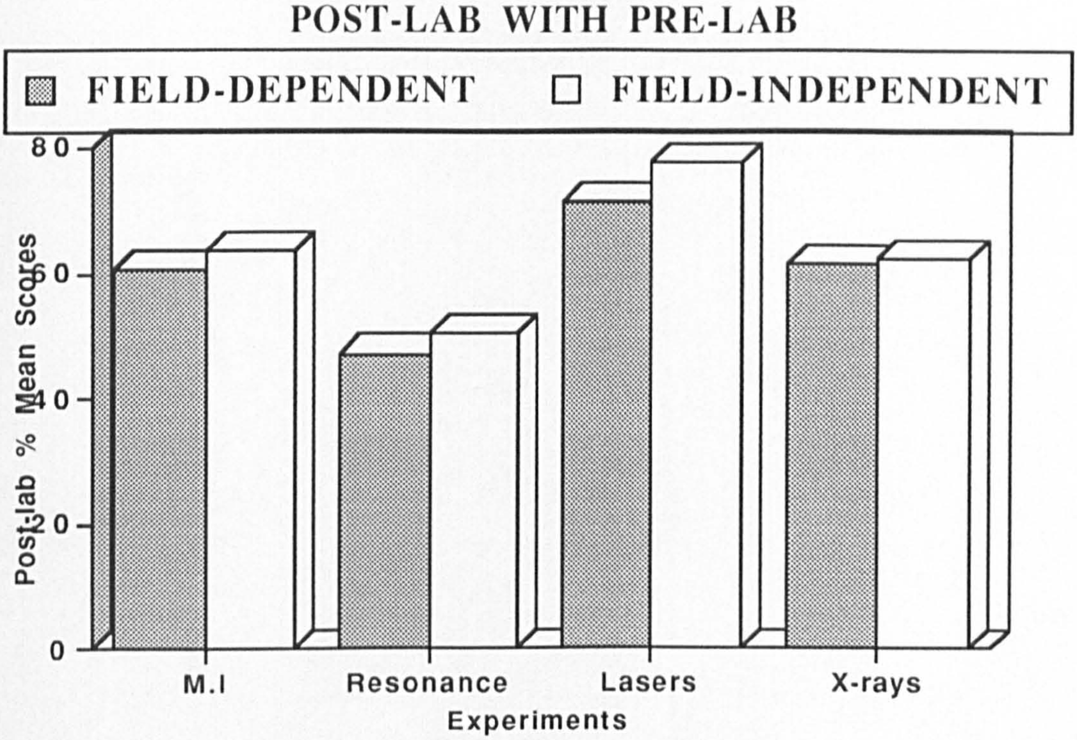
However the mean scores in the tables 7.4 and 7.5 confirms that the students performance in their post-labs, with pre-lab is better then without pre-lab (hypothesis-2). Field-independent students with pre-lab perform better then without pre-lab (hypothesis-3). Field-dependent students with pre-lab perform better then without pre-lab (hypothesis-4). Field-independent students with pre-lab perform better than field-dependent students with pre-lab (hypothesis-5). And field-dependent students with pre-lab performed better than field-independent students without pre-lab (hypothesis-6). It is evident from this that the pre-lab helped the students to improve their understanding to physics-II laboratory work and the field-independent learners in this sample performed better in Physics-II, post-lab work than field-dependent with pre-lab which may support, what was predicted by the hypotheses.

To gain further insight into the above table (7.4 &7.5), a comparison between field-dependent and field-independent students' of their post-lab work, with and without pre-lab, is shown into the columns on the following pages.



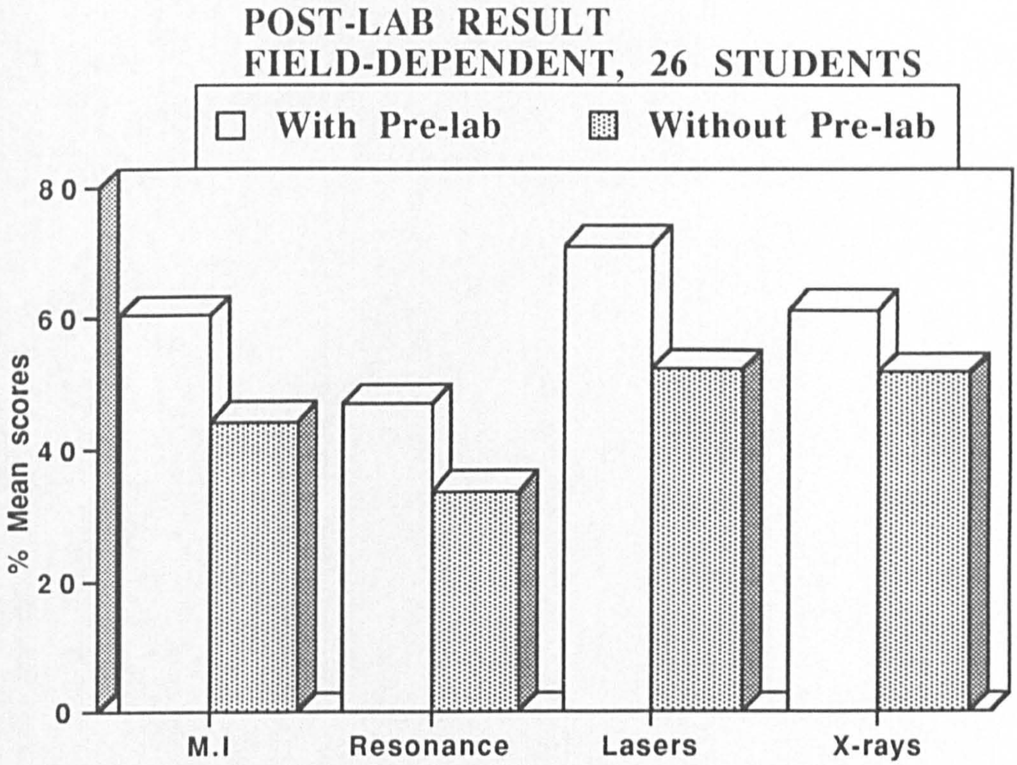
The comparison of above columns indicated that the post-lab performance of field-independent students is better than the field-dependent students' in the Lasers, Michelson Interferometer and Resonance experiments. The performance of field-dependent students is better than field-independent students in X-rays experiments, when both the groups performed their post-lab work, without pre-lab.

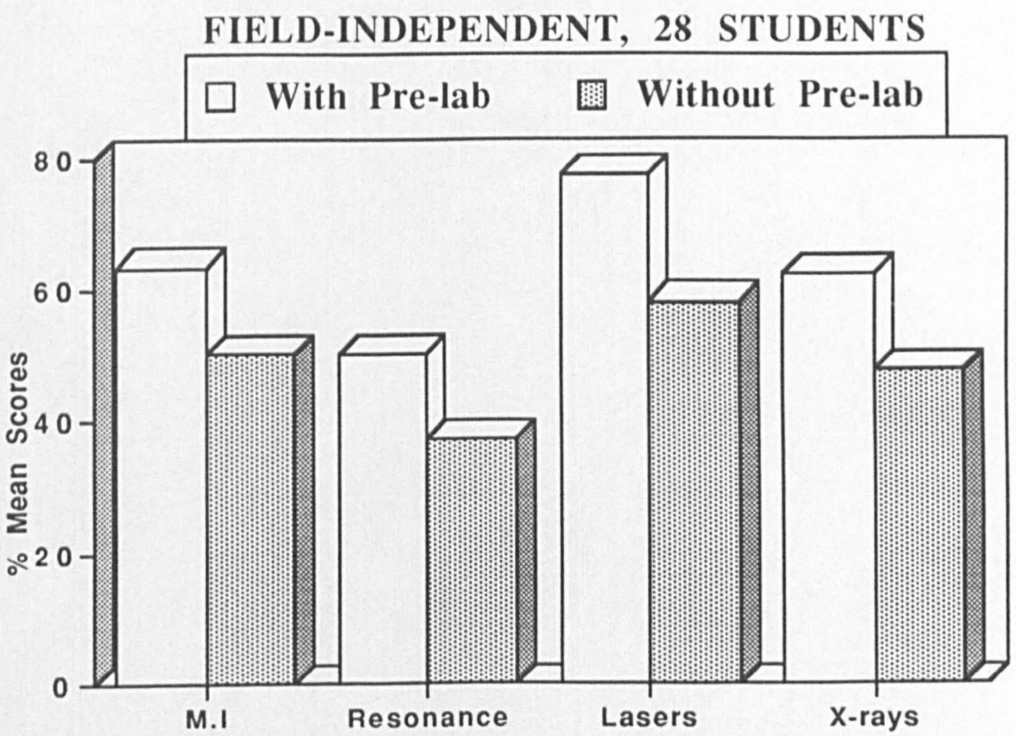
The X-rays experiment presents no challenge to the students. It is very largely a matter of routine data collection and analysis. Perhaps the field-independent students are bored by the experiment and their performance is comparatively not better than field-dependent students. The field-dependent students feel comfortable with this experiment and obtain their good results without too much intellectual effort.



The above columns show that the performance in post-lab work of the field-independent students is better than the performance of field-dependent students in the Lasers and the X-rays experiments. Furthermore in the experiments of Michelson Interferometer and Resonance, again field-independents' are slightly better when both the groups performed their post-lab work with pre-lab.

We concluded that field-independent students had on the whole benefited more than field-dependent, from the pre-labs. On the other hand if we consider the "restructuring abiltiy" (chapter-3, page 56), the finding supports that field-independent students are able to pick the 'signal' more easily than that of field-dependent students with special reference to their performance in physics-II practical work.





It is apparent from the above histograms that the post-lab performance of field-dependent and field-independent students with pre-lab is better than without pre-lab work in all the four experiments.

We conclude that the pre-lab helped the students to improve their understanding of Physics-II practical work. The gains of the field-dependent students are as good, or some time slightly better than field-independent students.

7.3 LABORATORY RESULT

It was the assignment of the physics-II demonstrators to assess the students' laboratory performance as a whole including different aspects such as procedure, skill in handling the apparutus, calculations, writing the results etc. The maximumm score for each experiment was ten.

The scores made by the sample students during the cognition phase, in each selected experiment i.e. with pre-lab and with out pre-lab procedures, have been analysed and the mean scores comparison is presented in the table 7.6 below.

To determine the significant difference between with and without pre-lab mean scores, t-test was used as we did in the last section of this chapter (post-lab result). The formula which we used to calculate the t-test value is;

$$t = \frac{\bar{X}_1 - \bar{X}_2 \sqrt{(N_1 + N_2 - 2)N_1 N_2}}{\sqrt{(N_1 S_1^2 + N_2 S_2^2)(N_1 + N_2)}}$$

and the degrees of freedom are taken from: df= $N_1 + N_2$ -2.

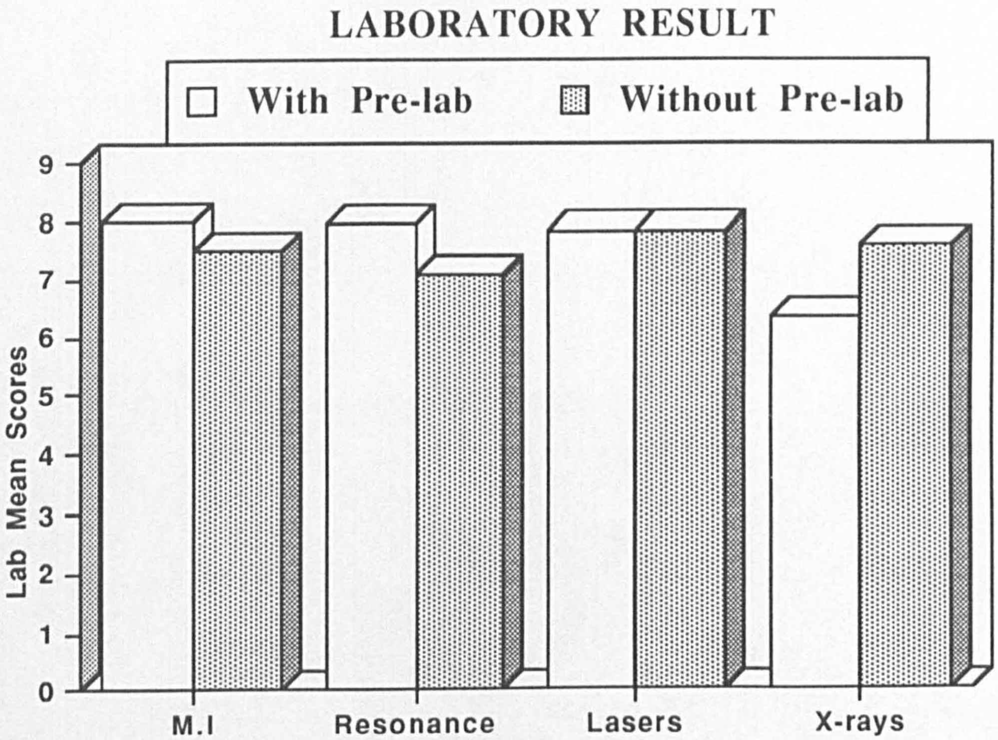
Table 7.6
LAB MEAN SCORES WITH AND WITHOUT PRE-LAB

Experiments	Michelson Interferometer	Lasers	Resonance	X-rays
With Pre-lab	7.99	7.84	7.97	6.36
Without Pre-lab	7.50	7.84	7.09	7.57
t-Test At 5% Level Of Significant	2.01>T.V df=63	0.00<T.V df=64	2.61>T.V df=63	3.54>T.V df=60

The t-test values in the last row of the table 7.6 indicated that there is significant difference between with and without pre-lab mean scores of the experiments Michelson Interferometer and Resonance, the t-test calculated value of the Lasers experiment is less then the tabulated value (T.V) which reflects no change and the X-rays experiment show significant difference contrary to our expectation.

This indicated that, with pre-lab work, students' understanding is improved significantly than that of without pre-lab work in the Michelson Interferometer and the Resonance experiments. The Lasers experiment reflects no significant change, and the result of X-rays experiment show an opposite picture of the prediction we made in hypothesis-2.

A more clear picture which emerged from the above table is shown in the histogram below.



It is apparent that there is no improvement of students' understanding with pre-lab for the Lasers experiment. The comparison of X-rays experiments' mean scores revealed a reverse picture from the prediction we made. However clear improvement of the students' understanding with pre-lab performance can be seen in the Michelson Interferometer and the Resonance experiments.

The above histogram show that the pre-lab helped the students to improve their understanding of physics-II practical work, in the experiments, Michelson Interferometer and Resonance, when measured by the demonstrators' marks for the lab reports.

7.3.1 FIELD-DEPENDENT/INDEPENDENT

In the section 7.2 of this chapter, the sample was separated into the groups i.e. the field-dependent/field-independent. To study the laboratory performance, the lab data is also divided in to the groups, according to the cognitive learning style of the sample students.

The students' lab performance within their cognitive style of learning is evaluated on the basis of the mean scores made by the groups and the t-test is used to determine the signicant difference between with pre-lab and without pre-lab mean scores. It is shown in the table 7.7 as under. These scores were awarded by the demonstrators on the basis of lab reports and were interpreted from the researcher.

Table 7.7
LAB MEAN SCORES FIELD-INDEPENDENT

Experiments	M.I	Resonance	Lasers	X-rays
With Pre-lab	8.31	8.25	8.15	6.45
Without Pre-lab	7.88	7.60	8.12	7.45
t-Test at 5% Level Of Significant	1.06<T.V df=24	1.21<T.V df=20	0.08<T.V df=21	1.24<T.V df=19

In the above table, t-test calculated values indicated no significant difference between with and without pre-lab, for all the four experiments. This shows that there is no significant change in field-independent students' understanding of physics-II experiments, while they had pre-lab.

Table 7.8
LAB MEAN SCORES FIELD-DEPENDENT

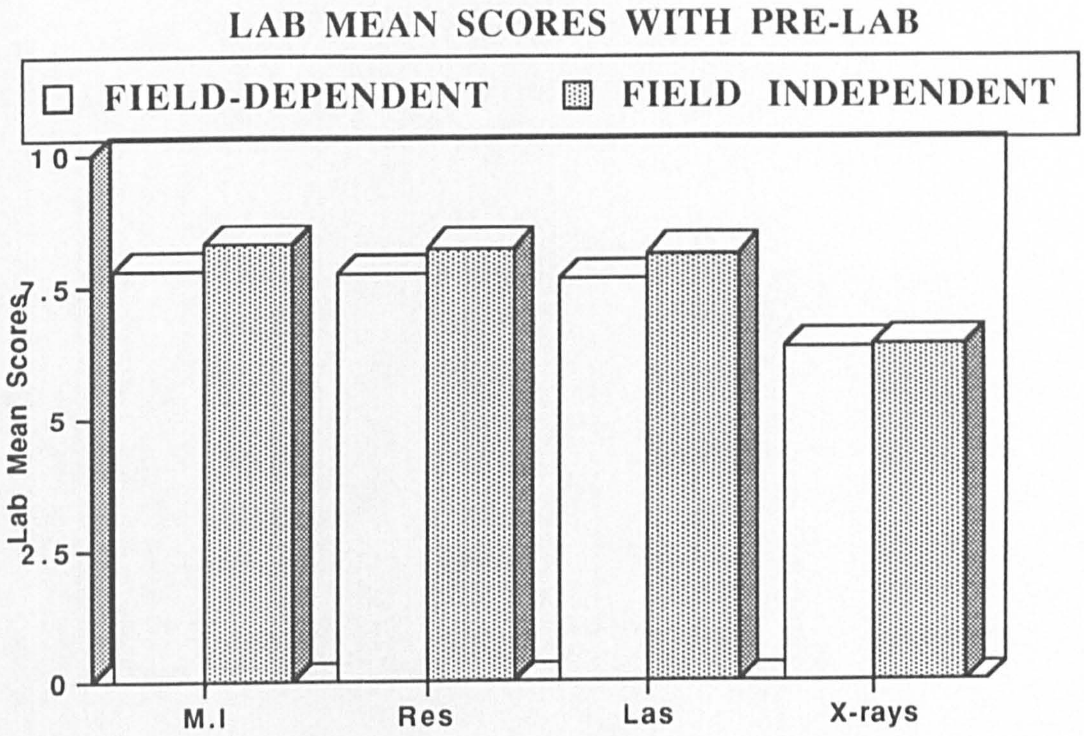
Experiments	M.I	Resonance	Lasers	X-rays
With Pre-lab	7.83	7.77	7.68	6.38
Without Pre-lab	7.43	7.17	8.30	7.80
t-Test at 5% Level Of Significant	0.89<T.V df=24	0.95<T.V df=22	1.48<T.V df=19	2.51>T.V df=20

In the table 7.8, t-test calculated values indicated no significant difference between with and without pre-lab, for the experiments Michelson Interferometer, Resonance and Lasers. Significant difference for the experiment X-rays is found which is negative to our expectations. This mean that pre-lab had not helped significantly to improve the field-dependent students' understanding of physics-II experiments.

However according to the tables 7.7 and 7.8 the mean scores of field-independent students in all the four experiments are better than the mean scores of field-dependent students. This may support the prediction we made in hypothesis-3. The performance of field-independent students with pre-lab is better than those without pre-lab, which may support hypothesis-2. Field-dependent students with pre-lab performed better than without pre-lab, this may support hypothesis-4. Mean scores of field-dependent students with pre-lab are not better than the mean score of field-independents without pre-lab, not supports hypothesis-6.

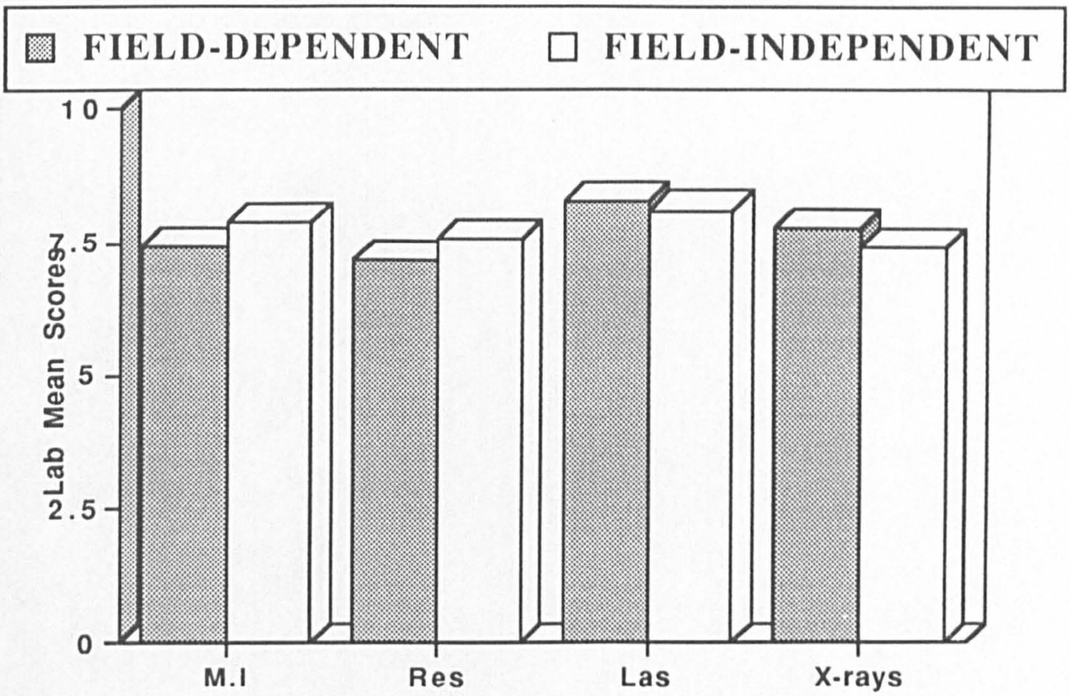
These results confirm the only predictions we made in hypotheses-2 to 5.

To have further insight into the lab mean scores presented in the tables 7.7 and 7.8 the comparisons are presented as histogram on the following page.

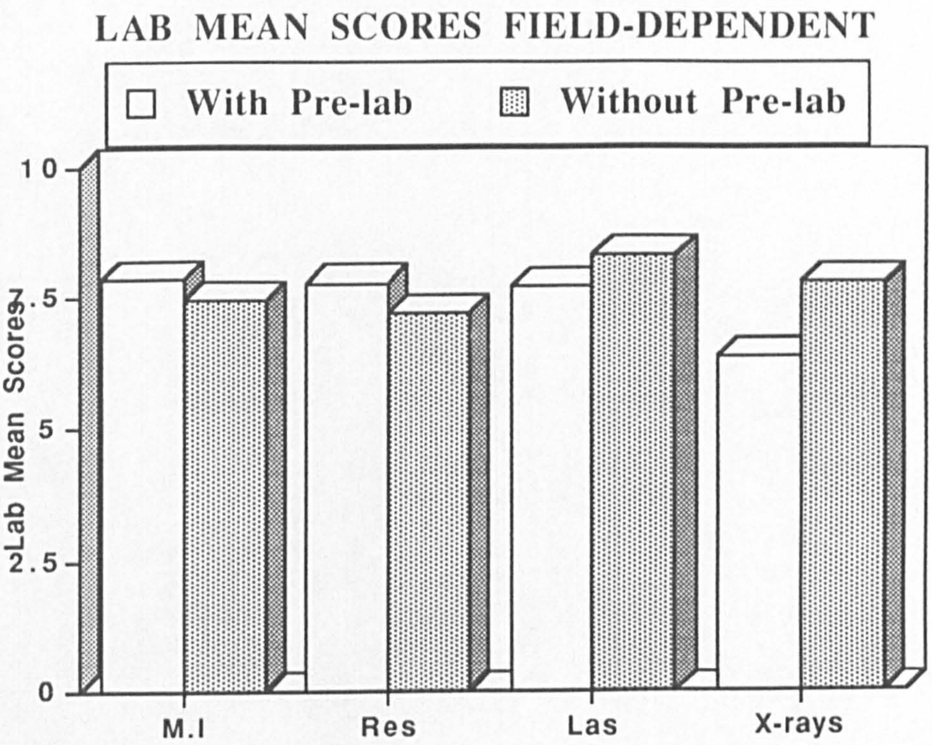


The above comparison of with pre-lab performance in physics-II lab indicated that field-independent students in the sample performed better than field-dependent students, but in the particular case of X-rays experiment, field-dependent showed their performance nearer to the field-independent students.

LAB MEAN SCORES WITHOUT PRE-LAB

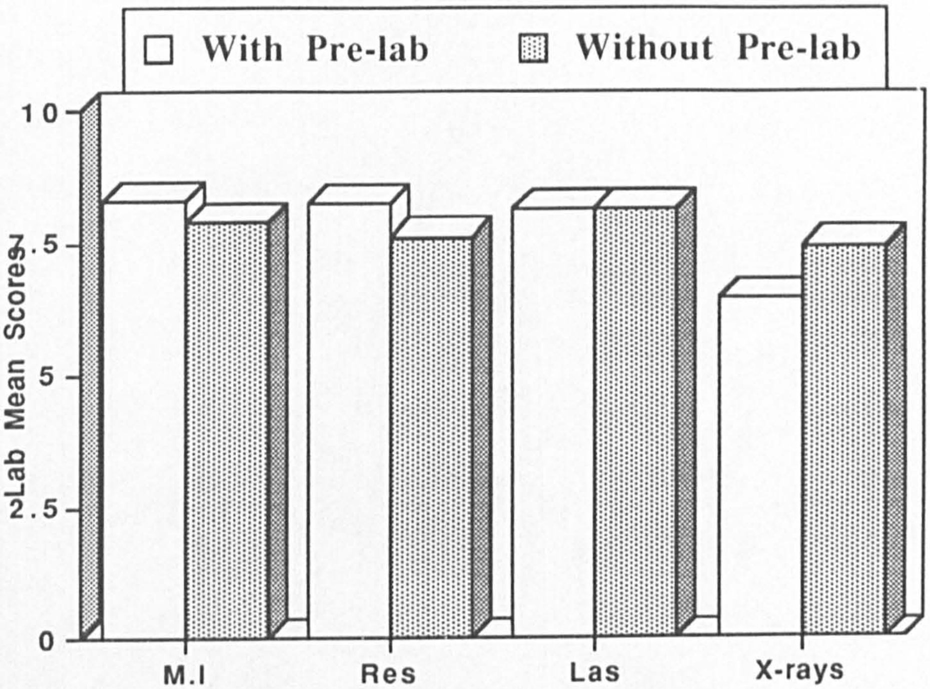


The above mean scores comparison of without pre-lab performance in physics-II lab indicated that field-independent students in the sample performed better than field-dependent students in the Michelson Interferometer and Resonance experiments, but field-dependent students performed nearer to the field-independent students in the Lasers and X-rays experiments. This was measured on demonstrators' marks.



The above lab mean scores comparison, with pre-lab and with out pre-lab performance of field-dependent students indicated that pre-lab helped to improve the students' understanding in the Michelson Interferometer and Resonance experiments, and a reverse picture emerged for the lasers and X-rays experiments. This was measured on demonstrators' marks.

LAB MEAN SCORES FIELD-INDEPENDENT



The mean scores picture of field-independent students in the above comparison is also similar to the field-dependent students' performance, but for the X-rays experiment here is less negative difference appeared between with and without pre-lab work.

We conclude that pre-lab helped the Physics-II field-dependent and field-independent students equally, in improving their understanding for Michelson Interferometer and Resonance experiments.

7.4 OVER ALL PHYSICS-II RESULT

All forms of assessment in the course we now compared in table 7.9. All students do the Michelson Interferometer, X-rays, Resonance and Lasers experiments and in addition to some other lab work chosen from a range of other experiments.

Table 7.9
PHYSICS-II COURSE BY PARTS

	MEAN SCORES	
Physics-II Course	**F.I**	**F.D**
Shapes	12.50	5.07
Class Marks (March)	61.43	59.29
Class Marks (December)	53.36	51.29
Av: Class Marks	57.39	55.27
Degree Exam	55.36	52.50
Library Project	8.14	7.93
Other Experiments	15.45	13.42
M. Interferometer	8.11	7.62
X-rays	7.07	7.02
Resonance	7.96	7.54
Laser	8.13	7.94

The above table, 7.9 indicated that the mean scores of field-independent students are better than field-dependent students in all the physics-II assessment. From this, it is evident that field-independent learners in this sample perform better than field-dependent learners, which may confirm what was predicted in the hypothesis (3), that is the overall performance of field-independents would be better than field-dependent in the physics-II course.

7.5 SUMMARY

The performance and evaluation of the sample students is shown in the results and discussion (phase-II). It is composed of 'cognition phase' which covers two terms of the academic session 1995-96.

The data analysis and results are presented in three steps that is: (1) the post-lab result, (2) the laboratory result and (3) the over all physics-II course result. Phase-II reflects the student understanding (cognition) to physics-II practical work.

The results of the experiment X-rays, do not support what was predicted by the hypothesis-1 and 2, but there is no significant disadvantage found in using the pre-lab for this experiment.

Generally, it seems that the results evidences supports, what was predicted by the hypotheses, raised in chapter five.

The results which emerged from the study of the sample tend to confirm that (1) pre-lab sheets fostered a positive attitude in the students towards the changes made in physics-II lab. (2) Pre-lab helped the students to improve their understanding of physics-II practical work. (3) field-independent students are better than field-dependent in physics-II course. (4) field-independent with pre-lab perform better then field-dependent students with pre-lab in physics-II practical work. (5) field-independent without pre-lab performed better then field-dependent without pre-lab students in physics-II practical work. (6) field-dependent with pre-lab performed better then field-independent without pre-lab students in only physics-II post-lab work. In all the comparisons of field-independent and field-dependent students where the preparation has been the same, field-independent students have achieved higher scores then field-dependent students. In this particular case of post-lab result the preparation is not the same, and the benefit resulting from the pre-lab sheets compensates the field-dependent students to obtained high scores then that of without pre-lab field-independent students.

The results described in this chapter show clearly the increase in understanding gained from the use of pre-lab sheets. It is to be expected that if a student has a better grasp of what he is doing, that is, if the primary picture of the experiment is clear and details of the method have been understood before the experimental work begin, than the student will feel more comfortable with his work, he will feel a greater sense of achievement and also he will be able to demonstrate understanding more convincingly.

CHAPTER EIGHT

OVERALL CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

There are several clear conclusions of this research which could have important lessons for designers of laboratory work in physics.

In the attitude area:

1. The use of pre-lab has significantly increased the frequency of positive attitudes towards the laboratory work.

2. The improvement of attitude was roughly equal among field-independent students and field-dependent students.

In the cognitive area:

1. The use of pre-labs significantly improved the performance of students as measured by the post laboratory exercises.

2. In general, field-independent students gained more than field-dependent students by the use of pre-lab.

3. Since post-labs are testing the understanding of principles encountered in the laboratory and also testing their use in unfamiliar situations, improvement in post-lab performance is a good indication of learning gain from the laboratory experience.

4. Although field-independent students' performance is generally higher than that of field-dependent students, field-dependent students with pre-lab significantly outperformed the field-independent students without pre-lab in the post-lab exercises.

5. Findings of 4 above would suggest that the effect of pre-lab is stronger than the learning style differences, in changing performance in post-labs.

6. On other measures in the course such as written exams and demonstrators' assessments, pre-lab students did better than those without pre-lab.

7. Post-labs, although used for measurement purposes, almost certainly have an

important function in consolidating what was learned in the lab, and helping the students to link new learning to existing knowledge and understanding.

8. It would seem to be reasonable to link an improvement in attitude with an improvement in learning. The learning gains recorded above certainly have an attitudinal as well as a cognitive component.

9. The six hypotheses raised in chapter five, have been very substantially supported by the results of this research, giving confidence in the predictive nature of the theory on which the work was based (Information Processing Theory). As a guide to teaching and learning the theory is clearly useful

8.2 RECOMMENDATIONS FOR ACTION AND FURTHER STUDY

1. To discourage recipe following and to encourage learning in a laboratory, **pre-labs** have an important role.

2. The nature of **pre-labs** needs further investigation, but simply asking students to read their lab-manual in advance is probably not good enough.

3. Pre-labs are known to exist elsewhere ranging from written work and pre-lab planning to computer programs which simulate the experiment so that pre-thinking can be done. Their relative effectiveness should be evaluated.

4. Consideration should be given to finding means of taking account of individual differences in learning style. It is not envisaged that students should be pidgeon-holed into various styles, but that more than one learning method should be offered and students encouraged to use the most congenial mode. Two experiments of this kind are in progress in the Centre for Science Education in which motivational styles (conscientious v curious) and thinking styles (visual v verbal) are being catered for. The indications are that students are responding well to these innovations.

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APPENDICES

APPENDIX-A (PAGES 231-232)

OBJECTIVES

APPENDIX-A

THE OBJECTIVES BEING USED AT UNDER GRADUATE LEVELS IN SOME OF THE UK's EDUCATIONAL INSTITUTIONS

STANDARD GRADE PHYSICS, AIMS AND OBJECTIVES

The Scottish Examination Board, (1990), developed the following aims and objectives for the Standard Grade Certificate of Education.

AIMS:

The course aims to contribute to pupil's general education by helping to make sense of the physical environment through scientific enquiry and to provide a suitable basis for further study in physics. The essence of such enquiry is problem solving, and thus in common with other sciences this course aims to develop the skills necessary to find solutions to scientific problems and through success and enjoyment to develop positive pupil attitudes.

OBJECTIVES:

As a result of following the course, pupils should acquire;

-**Knowledge And Understanding** of facts and ideas, techniques and the application of physics in society;

-**Skills** in applying their knowledge and understanding in problem solving;

-**Positive Attitudes** such as being open-minded and willing to recognise alternative points of view, prepared to show initiative and accept responsibility, and aware that they can take decisions which affect the well-being of themselves and others and quality of their environment.

UNIVERSITY OF EDINBURGH AIMS OF PHYSICS-II

University Of Edinburgh Department Of Physics, (1992/93), elaborated aims for Physics-II as under.

-"a desire on the Department's part to increase a student's appreciation of physics by placing a strong emphasis on both the understanding of physics and the ability to articulate that understanding by clear writing and exact expression;

-the expectations that industrial and professional bodies have of graduate physicists; And

-Physics-2 is a demanding, but rewarding, course. Whilst dealing with concepts often of great subtlety, it develops, alongside them, a description and understanding of every day phenomena using these very concepts".

UNIVERSITY OF DUNDEE, AIMS OF 2ND YEAR PHYSICS COURSE

University Of Dundee, Department Of Applied Physics, Electronics And Manufacturing Engineering, (1994-95), develop following aims for physics-2 laboratory course:

-To become proficient in experimentation by practice;

-To explore and understand in-depth some aspects of physics using experiments and demonstrations.

APPENDIX-B (PAGES 233-259)

RELEVANT PART OF THE PHYSICS-II LAB MANUAL

DIFFRACTION AND INTERFERENCE USING A LASER

(Ref. Jenkins and White, Ch. 15, 16, 17.)

Diffraction and interference phenomena of light waves can be quickly and easily examined utilising the coherence and directional properties of laser light. The Helium-Neon laser supplied provides an intense narrow beam of monochromatic coherent light.

PLEASE NOTE THAT THE LASER BEAM CAN CAUSE DAMAGE TO THE EYE. NEVER LOOK DIRECTLY ALONG THE LASER BEAM OR AT ITS FULL REFLECTION.

Experimental

Switch on the laser and check that the beam falls on the central portion of the frosted glass screen.

(1) Single slit diffraction

Mount the variable slit on the optical bench in the laser beam. Observe the diffraction pattern on the screen and note how the pattern changes as the slit width is reduced.

The distance, X_n , of the 'n'th minima from the centre of the pattern is given by

$$X_n = \frac{n\lambda D}{\alpha}$$

where λ = wavelength of light, a = slit width and D = slit-screen distance.

Select a slit width which gives a diffraction pattern with several secondary maxima. Pin a sheet of graph paper behind the frosted glass screen and note the positions of maxima and minima on the paper. Sketch qualitatively the diffraction pattern (i.e. graph of intensity vs. distance).

Measure D, the distance from slit to screen and a, the slit width (with a travelling microscope).

From your measurements calculate λ - give some thought to the choice of slit width and repeat if necessary.

Estimate carefully the error on your result.

NOTE

Fraunhofer diffraction patterns are usually produced by placing a diffracting system in a beam of plane monochromatic waves and observing the resulting diffraction pattern in the focal plane of a converging lens (i.e. equivalent to observing pattern at infinity). In the above experiment this was approximated by displaying the pattern on the screen placed at a large distance from the slit. In order to study diffraction effects produced by multiple slits and gratings it is necessary to increase the width of the laser beam. This can be achieved using the lens system shown in Fig. 1.

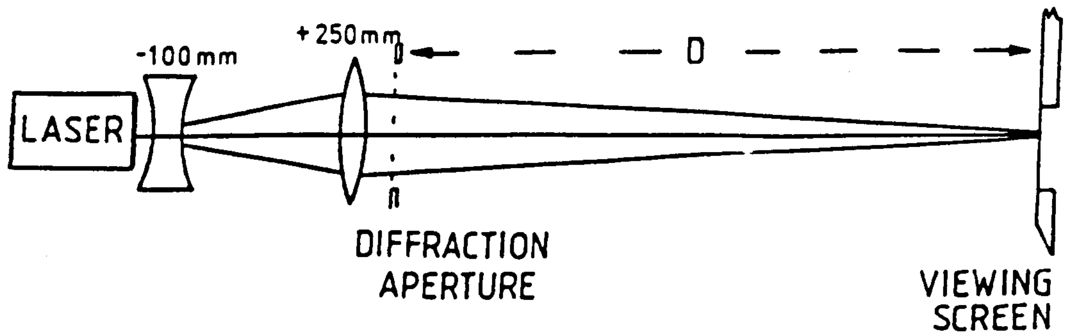


Figure 1

The concave lens is used to diverge the laser beam which is then focused on the distant screen by a convex lens. The diffracting system is placed just beyond the converging lens as shown in Fig. 1. Assemble the lens system as shown in Fig. 1 and adjust the position of the converging lens to produce a sharp focus of laser beam on the screen.

Insert the variable slit and note the improved definition of the diffraction pattern compared to that observed earlier.

(2) <u>Double slit diffraction</u>

The double slit and other diffraction apertures are printed on labelled slides.

Insert the double slit in the slide holder and put it on the optical bench in place of the variable slit.

Observe and sketch intensity graph of the diffraction pattern obtained. Note how the interference pattern is modulated by the single slit diffraction pattern.

Again mark the positions of the maxima and minima of the interference pattern and of the single slit diffraction pattern. Measure the separation of the slits with the travelling microscope or projector - a 35mm slide projector with calibration slide is available and may provide more accurate measurements of the slits and gratings slides. Calculate the wavelength of the laser light with errors.

($\lambda = \delta d/D$ where d = (centre to centre) slit separation. δ = separation of maxima or minima.)

(3) <u>Multiple slit diffraction</u>

Insert the slides of the 3, 4, 5 and 6 slit apertures in the laser beam and in each case sketch the intensity graph of the diffraction pattern. Note as the number of slits increases the brightness of the principal maxima increases, but the broad central patch within which the fringes lie does not change in size (though the fainter patches on either side of this central region become more visible as the number of slits increases), i.e. the interference pattern is again modulated by the single slit diffraction pattern. The separation of the principal maxima does not alter as the number of slits increases but their brightness increases and width decreases and a number of secondary maxima (equal to the number of slits minus two) appear in between the principal maxima.

4) Coarse grating

This development of principal maxima is further demonstrated by observing the pattern from the coarse grating 1 slide.

Note again the interference pattern is modulated by the single slit diffraction pattern.

Observe the diffraction patterns from coarse grating slides 2 and 3.

From your observations of these diffraction patterns for the three gratings estimate the ratio of the slit width and separation in each case. (See Jenkins and White Ch.16 "Missing Orders"- Fig. 16E and text.)

Note the separation of the principal maxima on the screen for coarse grating 1 and measure the grating element 'd' (separation of adjacent slits) with the travelling microscope or projector.

Calculate the wavelength of the laser light with errors.

(5) Crossed gratings and gauze

Insert coarse gratings 2 and 3 in the laser beam with their slit directions perpendicular.

Note that the resulting pattern is not just the sum of the separate patterns. New orders of diffraction have appeared. Observe the effect of rotating one grating relative to the other.

Fine gauze or fabric diffracts light in a similar manner.

Remove the coarse gratings and lenses and place the 'Optical Analogue' grating in the laser beam. This grating should be clamped by means of the hub so that the metal disc, on which a fine wire gauze is mounted, is free to rotate. Note the diffraction pattern obtained and use it to calculate the number of wires per unit length in the gauze.

Observe the effect of rapidly spinning the grating. The circular pattern obtained is analogous to that obtained by diffraction of electrons by thin carbon film. (See Electron Diffraction Experiment.)

(6) Diffraction by a fine wire

Observe and sketch the intensity pattern obtained by diffraction from a fine wire. Note that, apart from the region of the central maximum, where two extra minima occur, this pattern is identical to that produced by a slit of the same width as the wire.

Using the best estimate of the wavelength of the laser light obtained previously estimate the diameter of the wire from the diffraction pattern. (Measure the separation of minima away from the central maxima.) (Refer to section (1).)

Compare this value with a direct measurement of the diameter with a micrometer - given on the slide holder.

(7) Hologram

Set up the laser and lenses as shown below. This arrangement spreads out the laser light beyond the point 0 so that it cannot damage the eye. Place the hologram in the beam and look through it in the direction indicated.

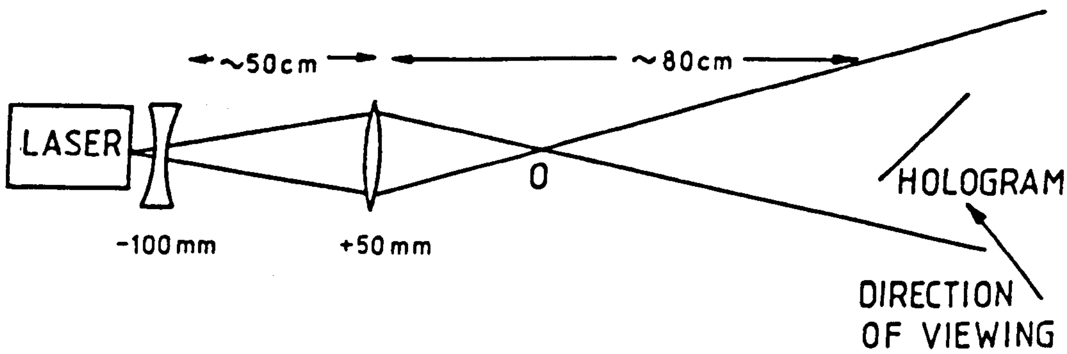


Figure 2

Study and note the three dimensional properties of the image seen.

Investigate the effect of masking part or most of the hologram.

Some of the effects which have been observed in the course of the experiment can be studied using a programme called **Diffract** which is available on the A3000 computer in the laboratory.

Complete the experiment by referring to p.14 of the manual which gives a general introduction to using the A3000, and then follow the instructions on p.15 to run **Diffract**.

Record the results obtained from **Diffract** in your record book.

X-RAYS

(Ref. Wehr, Richards and Adair, Ch.6.)

When the outer electrons of an atom are excited (e.g. in a gas discharge) the-excitation occurs with the emission of visible spectral lines characteristic of the atom (e.g. line spectrum of mercury discharge lamp).

In a similar manner if an atom is excited in such a way that an electron is ejected from one of its inner shells the atom de-excites with the emission of electromagnetic radiation as electrons cascade down from higher shells to fill the vacancy. This radiation in medium and heavy elements (where inner electrons are tightly bound) is in the X-ray region of the electromagnetic spectrum - the wavelengths being ~1000 times shorter than visible light.

X-rays are normally produced by accelerating electrons through a high potential and allowing them to strike an anode target. The resulting X-ray emission spectra has two components:

(i) A continuous or 'white' spectrum due to the deceleration of the incident electrons in the target.
and
(ii) A line spectrum superimposed on the continuous spectrum due to excitation of the target atoms. This line spectrum is thus characteristic of the anode material.

X-ray Crystal Spectrometer - 'Tel-X-Ometer'

The Tel-X-Ometer (commercial trade name for the instrument) supplied is similar in many ways to an optical spectrometer. The source in the Tel-X-Ometer is an X-ray tube with a hot filament cathode and a copper anode which operates at 20 kV or 30 kV (selection being made by mean of the red switch on the table of the instrument).

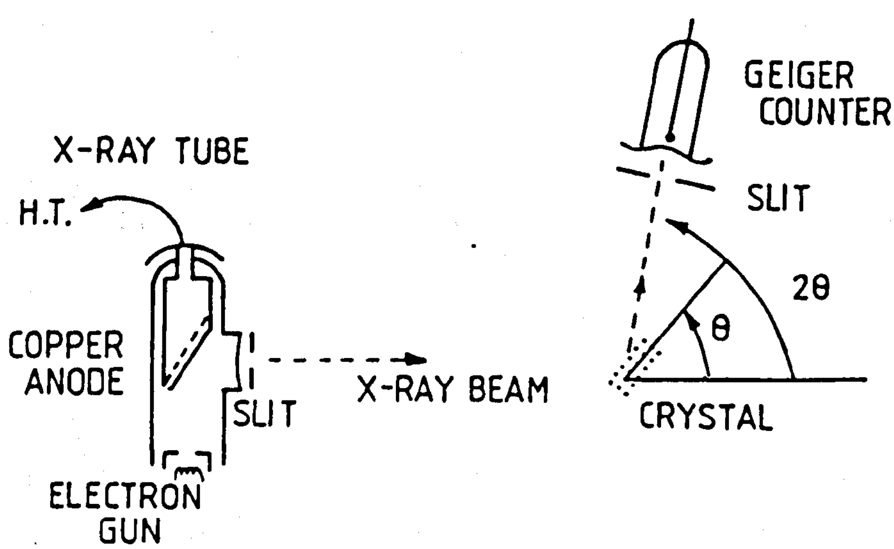


Figure 1: X-ray Crystal Spectrometer

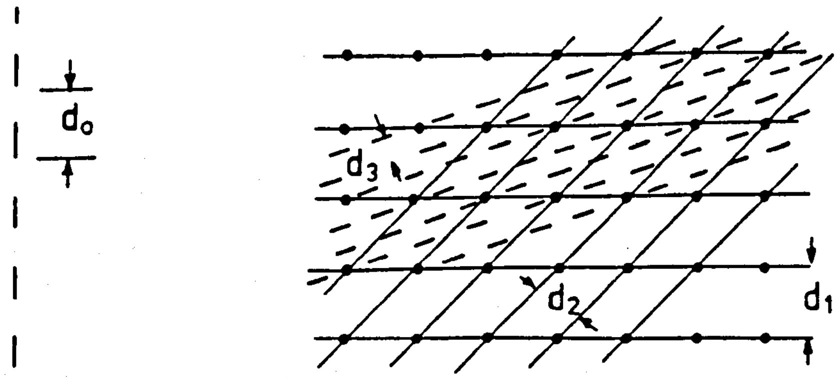
The X-ray beam is collimated by a 1mm vertical slit situated in the exit port of the X-ray tube.

Analysis of the X-ray spectrum is performed by reflecting the incident X-ray beam from a crystal situated at the centre of the Tel-X-Ometer table (c.f. diffraction grating in optical spectrometer). X-rays are strongly reflected from the crystal provided in the following relations are satisfied - Bragg Conditions:

(a) the angle of incidence = the angle of reflection ($= \theta$)
(b) $2d\sin\theta = n\lambda$

where d is the spacing of crystal planes. θ is the angle of reflection, n is an integer denoting the order of the spectrum (= 1, or 2, or 3, etc.) and λ is the X-ray wavelength.

A crystal differs from an optical diffraction grating in that the latter acts as a 1-dimensional object with a uniquely defined periodicity d. However a 3- dimensional crystal may be thought of as comprising an infinite set of crystal planes of difference spacings. This is illustrated by considering a very simple 2-dimensional regular array of atoms as shown.



a) OPTICAL GRATING (1-D ARRAY)

b) 2-D ARRAY OF ATOMS

A crystal plane is any set of planes which pass through all the atoms in the array. and three such are shown here. Note that they all have different spacings which are related by simple geometry.

The Tel-X-Ometer is constructed so that when the spectrometer arm is rotated through an angle of 2θ the crystal rotates through angle θ - as required in order to satisfy the first Bragg condition. This 2:1 drive mechanism is engaged by a 'Knurled Clutch Plate' at the centre of the table which when unscrewed allows the relative positions of the crystal post and spectrometer arm to be adjusted. Check that with the arm at zero on the 2θ scale the lines on the slave plate carrying the crystal post are accurately on the zeros of the θ scale and adjust if necessary.

THE TEL-X-OMETER IS FULLY INTERLOCKED TO PREVENT ACCIDENTAL EXPOSURE TO X-RAYS.
TO COMPLETE THE INTERLOCKS THE TRANSPARENT RADIATION COVER MUST BE LOWERED AND MOVED TO THE CENTRAL POSITION BEFORE THE E.H.T. (i.e. X-RAY BEAM) CAN BE SWITCHED ON. TO RELEASE THE RADIATION COVER IT MUST BE PUSHED TO THE SAME SIDE AS THE SPECTROMETER ARM. THIS AUTOMATICALLY SWITCHES OFF THE X-RAY BEAM.

The scattering X-rays are detected by means of a thin end window geiger counter and the X-ray intensity is indicated on a ratemeter or scaler timer.

Thus we have a single crystal X-ray spectrometer similar to that described in Wehr, Richards and Adair - see Fig. 1. The variation of X-ray intensity as a function of wavelength may be determined by measuring counting rate as a function of angle and, assuming d is known using the second Bragg relation to convert from angle to wavelength.

I Measurement of X-ray Spectrum and d for KCl, LiF and NaCl

Insert the geiger tube and holder in position 22 on the spectrometer arm and place the 1mm collimator in position 13.

Check that the red voltage selector is at 30 kV.

Set the time switch on the side of the unit to 5 minutes. Close and centrally align the transparent cover. Switch on power and X-ray beam. Both white and red lamps on the spectrometer table should light up and the geiger counter respond - if not, consult a demonstrator.

NOTE (i) TO SWITCH OFF X-RAY BEAM SLIDE THE TRANSPARENT COVER TO THE SIDE.

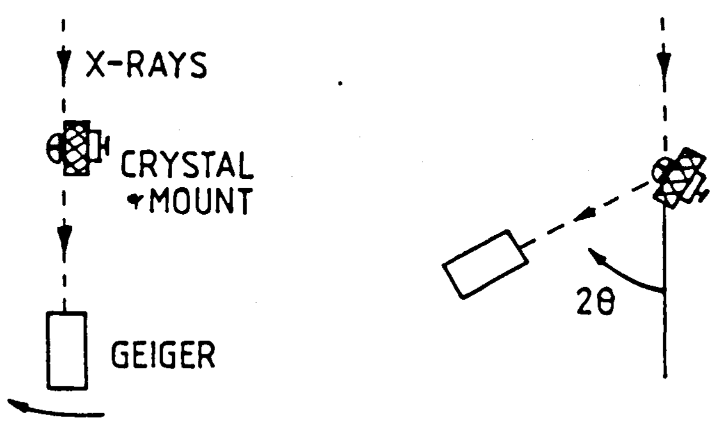
(ii) IF THE SPECTROMETER SWITCHES OFF DURING EXPERIMENT RESET THE TIME SWITCH AND SWITCH ON AGAIN.

Set the geiger operating voltage on the geiger plateau using the direct X-ray beam and ratemeter. The operating voltage is normally about 20V above threshold. (Refer to Appendix.)

Raise the transparent cover and carefully mount the LiF crystal vertically on the crystal post clamping the crystal firmly but not too tightly.

NOTE: To minimise absorption of the scattered X-rays in the crystal the crystal should be mounted and measurements made as shown in diagrams.

Plot a spectrum of counting rate against angle using the ratemeter.



Two prominent peaks should be observed at about $2\theta = 40° - 45°$ corresponding to the K_α and K_β lines being emitted by the copper anode and due to L to K and M to K transitions of the atomic electrons. These peaks are in the first order spectrum, i.e. $n = 1$ in equation (b).

If the intensity of these peaks are very low or very high (off scale on the ratemeter) ask the demonstrator to adjust the X-ray tube current.

NOTE: ON NO ACCOUNT SHOULD STUDENTS ALTER THE TUBE CURRENT THEMSELVES.

LiF is a cubic crystal of density 2.64 gm/cm^3. If the atomic weights of Li and F are 6.94 and 19.0 respectively calculate the interatomic spacing, d. (See Wehr, Richards and Adair - section 6.9.)

With this value of d use equation (b) to determine the wavelengths of the K_α and K_β lines of copper. Determine the corresponding energies of these lines in e.v.

Measure the corresponding spectrum for the KC1 and NaCl crystals. Try to observe peaks corresponding to second order, n = 2, (and higher orders ?) for these crystals.

Again, if necessary, have the demonstrator adjust the X-ray tube current for each crystal.

Use the measured K_α and K_β wavelengths of copper to determine the interatomic spacing d of these crystals.

Do the d spacings of your three crystals vary, one from another, as you would expect ?

II <u>X-Ray Absorption</u>

With the geiger arm at zero on the 2θ scale reset the lines on the slave plate to zero on the θ scale.

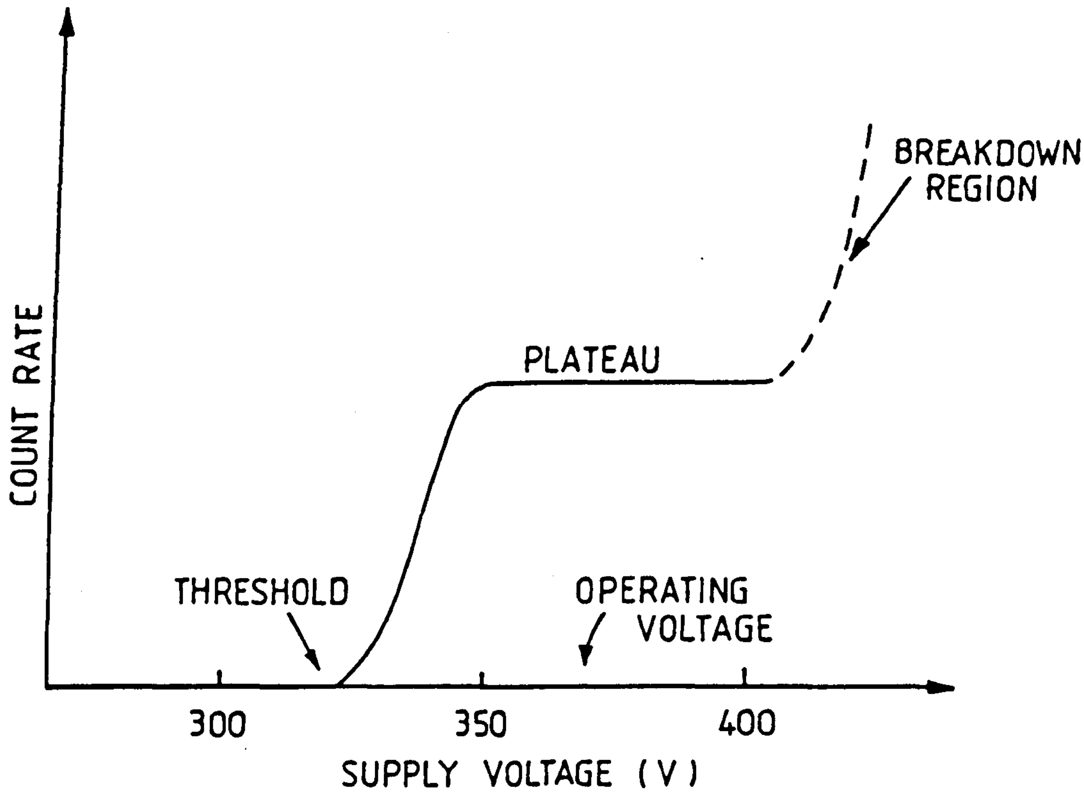
Leaving the collimating slit in place, insert the slide containing nickel foil in front of the geiger counter, and insert the LiF crystal in its mount. Check that you have a healthy count rate, and ask the demonstrator to adjust the tube current as necessary.
DO NOT ADJUST THE TUBE CURRENT DURING THE REST OF THE EXPERIMENT.
Using the ratemeter, measure the scattered X-ray spectrum from the LiF crystal with the nickel foil in place.

Repeat for the copper and cobalt foils.

Plot the spectra for the three different foils on the same graph and compare them. Discuss the significance of your results. (See Wehr, Richards and Adair section 6. 7.)

APPENDIX: Geiger Counter Operation

Typical Operating Curve



Do not increase voltage into the breakdown region. Operating voltage should be set about 20-30V above threshold.

MICHELSON INTERFEROMETER

(Ref. Jenkins and White 'Fundamentals of Optics' p.271.)

The form of Michelson Interferometer used in this experiment is illustrated below:

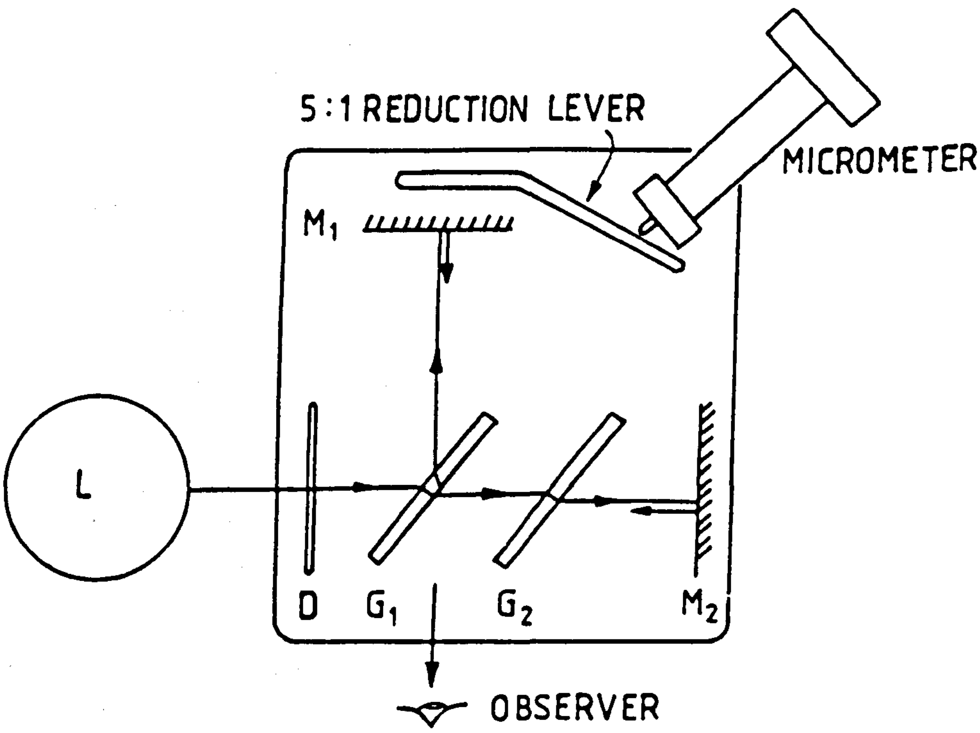


Figure 1

Light from the extended source L is diffused by screen D and split into two parts by partial reflection at plate G_1. The resulting two light beams then follow different paths and after reflection at M_1 and M_2, are brought together again to produce interference fringes (i.e. interference by 'Division of Amplitude' cf 'Division of Wavefront' e.g. Young's Double Slit experiment). The plate G_2 is inserted to equalise the path lengths in glass of the two light beams.

FORMATION OF FRINGES

(a) Circular Fringes - produced with monochromatic light when the mirror M_1 and M_2 are exactly perpendicular. The formation of these fringes may be more readily understood by considering figure 2 which illustrates the essential features of the interferometer. In this figure M_2 has been replaced by M'_2, the reflection of M_2 in G_1 as seen by observer.

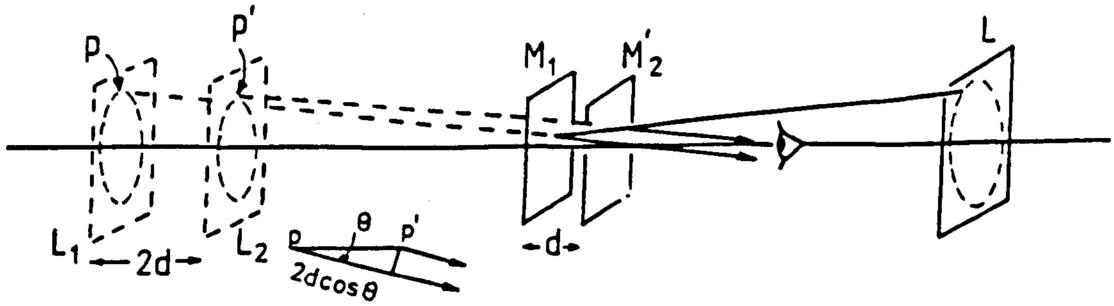


Figure 2

Due to reflection in the real interferometer the source L appears to be behind the observer who sees two virtual images of L, namely L_1 and L_2 in M_1 and M'_2. Hence the simplified diagram of the interferometer shown in figure 2. If M_1 is parallel to M_2 and if the separation M_1 and M'_2 is d then the distance L_1 L_2 will be 2d.

With incident light of wavelength λ when $2d = m\lambda$ all light reflected normal to the mirrors will be in phase. However rays reflected at an angle θ will not in general be in phase.

The path differences from rays coming to the eye (focused to receive parallel light) from corresponding points P and P' is

$$\delta = 2d\cos\theta \text{ (which increases as } \theta \text{ decreases.)}$$

Thus when $2d\cos\theta = m\lambda$ the rays will reinforce and produce a maxima (assuming there are no phase changes introduced by the reflections of the light beams). Thus maxima, and minima, will be in the form of circles about the foot of the perpendicular from the eye to the mirrors.

(b) Parallel Fringes are produced when M_1 and M'_2 are not exactly parallel. This is because the path difference across the field of view is due primarily to the variation of the thickness of the wedge shaped 'air film' between the mirrors. As d decreases the fringes move across the field; a new fringe crossing the centre of the field each time d changes by $\lambda/2$.

(c) White Light Fringes are only observed when the path difference is so small that it does not exceed a few wavelengths. Since white light contains all wavelengths between 400nm and 700nm fringes for a given colour are more widely spaced the greater wavelength. Thus fringes of different colours only coincide at $d = 0$.

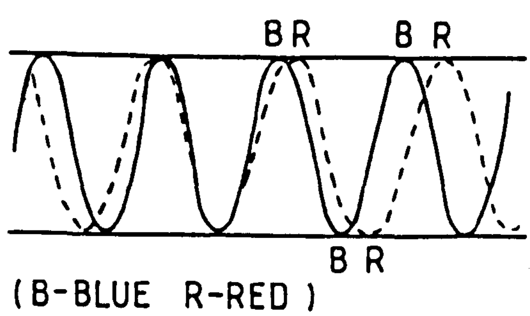


Fig. 3

Fringes of different colours begin to separate on either side of the central fringe and after 8 to 10 fringes so many colours are present at one point that the resultant colour is essentially white (figure 3).

Procedure

Switch on the mercury lamp and clip the metal pointer to the diffusing screen, D. Put your eye, as shown in figure 1, a few inches away from the instrument. Three reflected images of the pointer can be seen. Interrupt the light paths to M_1 and M_2 and you will see that one image is reflected from mirror M_2 and two from M_1 .One of these images is fainter than the other and is due to reflection from the unsilvered surface of G_1 .
Adjust the screws at M_2 so that the image from M_2 coincides exactly with the major image from M_1 . Fine fringes will be made visible, located between infinity and the surface of M_1 . These fringes can be made larger and eventually circular by fine adjustment of the screws at M_2 .

To obtain the zero path difference ($\delta = 0$), turn the path length control micrometer, moving mirror M_1 so that the circular fringes move inwards and become more widely spaced. Obtain the largest possible fringe that you can be sure is moving inwards for particular direction of movement of M_1 . **Remember this direction.**

Now adjust the screws at M_2 to produce about ten vertical fringes across the field of view. Switch the tungsten lamp on and the mercury lamp off and note the micrometer position. Continue turning the path length control **slowly** in the same direction as before until a group of bright coloured fringes (white light fringes) appears, while keeping your eye focused on the mirror. If you are unsuccessful you have either turned the control too quickly or in the wrong direction so go back to the recorded position and try again. The centre of this pattern should be black (why ?) but may not be due to mirror coatings.

When the white light fringes are visible, record the zero fringe setting on the micrometer.

Calibration of the Interferometer and Measurement of the average wavelength of the Sodium D lines.

The instrument is designed to have a 5:1 arm reduction ratio. However due to previous use (and misuse) this may no longer be the case and it is necessary to check this ratio.

Using the mercury lamp with the green filter obtain a fringe pattern and adjust the mirrors so that a pattern of reasonably spaced circular fringes is obtained.

Count a suitable number of fringes, Δm, disappearing (or appearing) at the centre of the pattern and note the corresponding movement on the micrometer. The actual distance moved by the mirror, Δd, may be calculated using the formula $2\Delta d = \Delta m\lambda$ (refer to previous page and note that at the centre of the pattern $\theta = 0$). Using the standard wavelength of the mercury green line, 546nm, calculate the arm reduction ratio of the instrument and estimate the accuracy of the measurement. In all subsequent measurements assume 5:1 reduction ratio unless your results indicate that this is not valid (in which case consult demonstrator).

Replace the mercury lamp with the sodium one and measure the average wavelength of the sodium D-lines.

(Note: If the fringe pattern from the sodium lamp is not clear but diffuse and indistinct adjust the micrometer until a clear pattern is obtained before making measurements - see next section.)

Determination of the Separation of the Sodium D lines

Using monochromatic light the circular fringes are visible for very long path differences in the interferometer. If however there are several wavelengths present in the source the fringes formed by different components will be differently spaced and will mask all interference at large values of d (c.f. white light fringes).

If the source consists of two closely spaced lines of wavelengths λ_1 and λ_2 $(\lambda_1 \; \lambda_2 \; \lambda_{av})$ the 'clarity' or 'visibility' of the fringe pattern fluctuates regularly through maxima and minima as the path difference is increased. This fluctuation is caused by the two fringe patterns corresponding to the two wavelengths getting in and out of step as d is varied. With circular fringes the path difference d can be adjusted to give a sharp fringe pattern for both wavelengths (at least near the centre of the pattern). If the separation of the mirrors is now increased by δ the path lengths for the two wavelengths at the fringe centre is increased by

$$2\delta/\lambda_1 \text{ and } 2\delta/\lambda_2 \text{ wavelengths.}$$

These are obviously different numbers and when the difference between them is ½ the centre of the fringe pattern for one wavelength is light when that for the other is dark, i.e. minimum visibility. Thus the next maxima in visibility will occur when

$$2\delta/\lambda_1 - 2\delta/\lambda_2 = 1$$

$$\text{i.e. } d = \frac{\lambda_1\lambda_2}{2(\lambda_1 - \lambda_2)} = \frac{\lambda_{av}^2}{2(\lambda_1 - \lambda_2)} \quad \text{where } \lambda_{av} = \frac{\lambda_1 + \lambda_2}{2}$$

The strong yellow line in the spectrum of sodium consists of two such closely spaced lines - the sodium D doublet. This doublet can barely be resolved by a spectrometer and although the average wavelength λ_{av} can be measured the separation of the doublet cannot be determined with any accuracy.

Procedure

Using the sodium lamp adjust the instrument to obtain circular fringes. Observe the fluctuation in clarity of the pattern as the micrometer is moved slowly by a few turns.

Determine accurately a value for d - the distance moved by the mirror between each position of minimum (or maximum) clarity. Can you use the position of zero path difference to increase accuracy ?

Does this correspond to a position of maximum or minimum clarity ? Using the measured value of λ_{av} for the sodium D lines calculate $(\lambda_1 - \lambda_2)$ for the sodium doublet and estimate your accuracy.

Measurement of the Refractive Index of Air

Theory

Assume the index of refraction of the gas in a cell of length L inserted in one arm of an interferometer is μ_i and μ_j when the pressure in the cell is P_i and P_j respectively. The change in optical path length through the cell is equal to $L(\mu_i - \mu_j)$ when the pressure changes from P_i to P_j. Thus we have (c.f.$2\Delta d = \Delta m\lambda$)

$$2L(\mu_i - \mu_j) = (m_i - m_j)\lambda$$

where m_i and m_j denote the order of the fringe at the centre of the pattern when the pressure is P_i and P_j respectively in the cell.

Now the refractive index of air is very close to 1. Let $\mu = 1+\sigma$. Thus we get

$$2L(\sigma_i - \sigma_j) = (m_i - m_j)\lambda$$

Assuming s is proportional to pressure P, i.e. $\sigma = kP$ (a reasonable assumption for many gases), then we get

$$P_i - P_j = \frac{\lambda}{2Lk}(m_i - m_j)$$

or

$$\Delta P = \frac{\lambda}{2Lk}\Delta m$$

Hence a graph of pressure in the cell against order of fringe will have a gradient of $\frac{\lambda}{2Lk}$.

Procedure

Insert the gas cell length L (L = 4.93cm) in one arm of the interferometer and the compensator plates in the other. Again using the mercury lamp and filter obtain a suitable fringe system as before.

Slowly evacuate the cell and measure the number of fringes appearing or disappearing at the centre of the pattern as a function of pressure. The pressure is measured by the manometer. When the cell is completely evacuated slowly admit the air and repeat the measurements. Plot graphs of pressure against number of fringes for both sets of readings and hence evaluate k from the gradients, taking a suitable average of the two results. Using $\sigma = kP$ evaluate σ and hence the refractive index of air, μ, at standard atmospheric pressure and room temperature (note that standard atmospheric pressure = 760mm of Hg).

Using the fact that $(\mu-1)$ is inversely proportional to absolute temperature, from your result calculate the refractive index of air at STP (0°C and standard atmospheric pressure) and compare your experimental value with the accepted value as given for example in Jenkins and White.

RESONANT SYSTEMS

(Ref. French "Vibrations and Waves".)

Resonance phenomena occur in every field of physics from resonances in electrical circuits to nuclear resonances. In each case the resonance is produced by an interacting force whose frequency corresponds to the natural frequency of the oscillating system. The mathematical treatment of all of these forced oscillators is essentially the same. We shall study both mechanical and electrical resonance.

For a mechanical system the equation of motion is that of a damped simple harmonic oscillator, of natural undamped frequency, ω_0, subject to an oscillating driving force. i.e.

$$M\frac{d^2x}{dt^2}+b\frac{dx}{dt}+kx=F_0\sin\omega t$$

where M is the mass of the system, $b\,{}^{dx}/_{dt}$ is the damping force, kx is the restoring force,

$F_0 \sin\omega t$ is the driving force, and $\omega_0=\left(\frac{k}{M}\right)^{\frac{1}{2}}$

The solution of this equation shows that after initial transient effects have disappeared, the system will oscillate at the angular frequency of the driving force, ω, with an amplitude

$$A=\frac{{}^{F_0}/_{M}}{\left[\left(\omega_0^{\,2}-\omega^2\right)^2+\frac{b^2\omega^2}{M^2}\right]^{\frac{1}{2}}}$$

and also that the motion differs in phase from the applied force by an angle δ given by

$$\tan\delta=\frac{b\omega}{M\left(\omega_0^{\,2}-\omega^2\right)} \qquad \text{i.e. } 0\le\delta\le\pi$$

Thus it is seen that, for light damping, the amplitude of oscillation will show a maximum when

$$\omega^2{}_m=\omega_0^{\,2}-\frac{\frac{1}{2}b^2}{M^2} \qquad \text{i.e.}\,\omega_m\approx\omega_0$$

i.e. the angular frequency of the driving force equals the natural angular frequency of the undamped system.-----Resonance.

Also we see that

(1) At resonance $(\omega=\omega_0)$ the phase angle $\delta={}^{\pi}/_{2}$, i.e. the displacement of the system lags the driving force by ${}^{\pi}/_{2}$.

(2) When $\omega \ll \omega_0$, $\delta \sim 0$, i.e. the displacement of the system is approximately in phase with the driving force.

(3) When $\omega \gg \omega_0$, $\delta \sim \pi$, i.e. the displacement of the system is in antiphase with the driving force.

An equivalent electrical system is a driven series LCR circuit, which is described by the equation:

$$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{q}{C}=V_0\sin\omega t$$

The natural resonance frequency $\omega_0=\frac{1}{\sqrt{LC}}$,

and the voltage across the capacitor is:

$$V=\frac{V_0/LC}{\left[\left(\omega_0^2-\omega^2\right)^2+(\gamma\omega)^2\right]^{\frac{1}{2}}}\quad \text{where } \gamma=\frac{R}{L}$$

The phase difference δ between V and the applied voltage is given by

$$\tan\delta=\frac{\gamma\omega}{\omega_0^2-\omega^2}.$$

It can be shown that the maximum value of V, i.e. V_m occurs at a frequency ω_m where.

$$V_m=\frac{\frac{V_0}{LC}}{\gamma\left(\omega_0^2-\frac{\gamma^2}{4}\right)^{\frac{1}{2}}}=\frac{\frac{V_0}{RC}}{\left(\frac{1}{LC}-\frac{R^2}{4L^2}\right)^{\frac{1}{2}}}$$

and $\omega_m^2=\omega_0^2-\frac{\gamma^2}{2}=\frac{1}{LC}-\frac{R^2}{2L^2}$

If Q is defined as $Q=\frac{\omega_0}{\gamma}=\frac{1}{R}\left(\frac{L}{C}\right)^{\frac{1}{2}}$ then if ω_1 and ω_2 are the frequencies for which V is decreased by a factor $\sqrt{2}$, provided Q is sufficiently large (say >0.5) we find

$$(\omega_1-\omega_2)\doteqdot\omega_0\left(\frac{1}{Q}+\frac{1}{8Q^3}\right)$$

Hence the width of the resonance curve is more or less inversely proportional to Q.
We can see that V exhibits the same variation with frequency as the amplitude A for the mechanical system. Indeed there is a close analogy between resonant mechanical and electrical systems which is summarised below.

Mechanical	Electrical
Displacement x	Charge q
Driving force F_0	Driving voltage V_0
Mass M	Inductance L
Viscous force constant b	Resistance R
Resonant frequency $\left(\frac{k}{M}\right)^{\frac{1}{2}}$	Resonant frequency $\frac{1}{(LC)^{\frac{1}{2}}}$
Resonant width $\gamma=\frac{b}{M}$	Resonant width $\gamma=\frac{R}{L}$

MECHANICAL RESONANCE

Apparatus

In this experiment the oscillating system is a narrow metal bar which is clamped at one end with a damping plate at the other end. The driving force is provided by a mechanical vibrator. driven by a variable frequency oscillator and coupled to the bar by a piece of elastic, at a point about a quarter way along the bar.

A small coil is mounted on the bar and is placed between the pole faces of a permanent magnet. The motion of the bar is conveniently displayed on one beam of the double beam oscilloscope by amplifying the induced signals in this coil due to its motion through the magnetic field.

A similar system of coil, magnet and amplifier is attached to the vibrator.

NOTE (1) The amplifiers used are integrating amplifiers. Why? (Hint; Recall Faraday's Law what is the signal in the coil proportional to?).

(2) The amplifiers require ± 12V - the supply for this is on the bench at the side of the lab.

(3) The vibrator should be driven by the low output impedance (3Ω) terminals of the oscillator.

The signal from the oscillator which drives the vibrator should be displayed on the second beam of the oscilloscope.

The two traces on the oscilloscope now permits an investigation of the amplitude of the motion and the phase difference, δ, as a function of frequency of the driving force.

Since the scale on the variable frequency oscillator is rather poor a more accurate measurement of this frequency is provided by sending a signal from the output of the oscillator to a Digicounter. This is used in the PERIOD mode and the frequency obtained from $f\text{Hz} = \frac{1}{p}\text{s}$

A diagram of the apparatus is shown in Fig. 1.

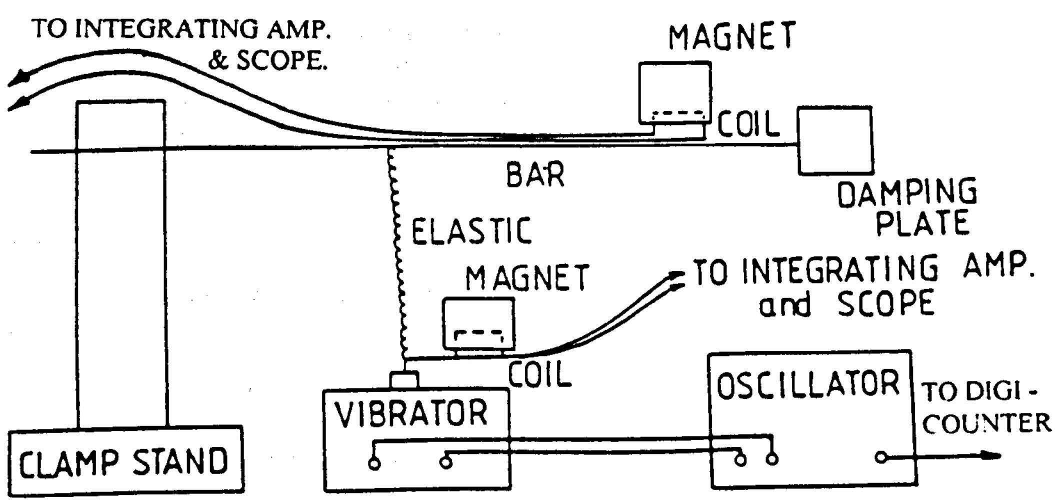


Figure 1

Procedure

Adjust the length of the bar to be $\gtrsim 20$cm.

Carefully graph:

(a) the amplitude of the motion against the frequency of the driving force (using the timer);

(b) the phase difference δ measured on the oscilloscope as a function the frequency of the driving force. (From Figure 2):

$$\delta = \left(\frac{AB \times \pi}{AC}\right).$$

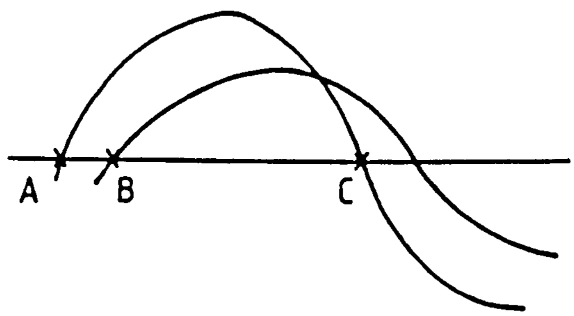


Figure 2

Very rapid changes will take place in the region of resonance and particular care should be taken (with sufficient measurements) in this region.

The oscillating bar can be 'damped' by placing the damping plate at the end of the bar between the pole faces of a strong permanent magnet - explain!

Repeat the above measurements for the 'damped' oscillator and graph your data together with the previous data. Compare your observations with the theoretical predictions and discuss any discrepancies.

ELECTRICAL RESONANCE

Apparatus

In this part of the experiment we use a PC computer equipped with an ADC/DAC interface, to generate a sinusoidal output voltage of varying frequency (from 0 to 2000 Hz) which is applied to a series LCR circuit. The computer is able to record the voltage V across the capacitor, and the variation of V and the phase shift δ with frequency can be displayed on the computer screen.

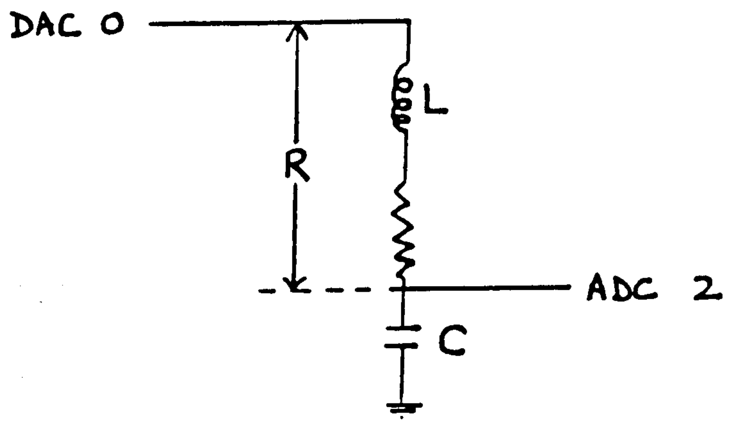
Procedure

The instructions for operating the computer are contained in the appendix which is at the end of the instruction sheet.

1. Investigation into the effect of varying R for fixed values of L and C.

Connect a series combination of R, L and C to the interface board as shown.

(NOTE: The value of R used in the experiment includes the self-resistance of the inductance in series with the resistance of the resistor. R is measured with the meter provided.)



Make sure the program controlling the experiment is working properly by referring to the operating instructions described in the appendix. The appendix also contains information about the different commands and options provided by the program.

For fixed values of L and C, select 3 different values of R. For each value of R measure:

(a) V_0

(b) V_m

(c) ω_m

(d) $\omega_{\delta=90°}$ (i.e. the frequency for a phase shift $\delta = 90°$).

(e) ω_1 and ω_2 (i.e. the frequencies for which V is decreased by a factor $\sqrt{2}$ from V_m).

Compare the measured values of V_m, ω_m, $\omega_{\delta=90°}$ and $(\omega_1 - \omega_2)$ with the theoretical formulae.

Comment on any trends that are apparent in the level of agreement between the measured and theoretical values.

Using the 'D' command, compare the measured resonance curves with the theoretical prediction, and vary the value of R which you type into the program until the best fit between the experimental and theoretical curves is found. Comment on the values of R obtained.

2. Investigation into the effect of varying C for fixed values of R and L.

For 5 different values of C, but fixed values of R and L draw a suitable graph to test the equation

$$\omega_m^2 = \frac{1}{LC} - \frac{R^2}{2L^2}.$$

(Run through the complete range of parameters before taking measurements to check the programme will accept them.)

NOTE: Some of the effects which have been observed in this experiment can be studied using a program called Damp SHM which is available on the A3000 computer in the lab. Complete the experiment by referring to pages 14 and 16 of the manual.

APPENDIX.

Users guide.

To start the programme, the user should type **menu** at the DOS prompt. This will bring up the main menu.

Main Menu.

The main menu has 3 options:
1. CR CIRCUIT
2. LCR CIRCUIT
3. QUIT

changes as the highlight moves to each option.

When the menus is brought up the first option is highlighted. By using the up and down arrow keys, the option highlighted is changed. To select the highlighted option, the ENTER key is pressed. Select the LCR circuit option. At the bottom of the menu there is an area entitled HELP. This contains a few lines of text describing each option. This HELP text changes as the highlight moves to each option.

LCR Circuit Option

When this option is selected a screen is displayed allowing you to enter various parameters. These parameters are:-
1. The measured resistance of the circuit obtained from a meter. (The inductor has a resistance contributing to the total resistance of the circuit (ohms).)
2. The capacitance (μFarads)
3. The inductance (mHenries)

This screen also displays a few lines of text informing you about how to connect up the circuit to the DAC and ADC.

When all the values are entered the screen informs you to press any key to continue or to press the escape key to quit and return to the main menu. If the escape key is not pressed the graphics display is brought up on the screen.

Graphics Display

The graphics display shows a graph of voltage amplitude or phase change against frequency. The frequency scale is in the range of 0-2000Hz. The theoretical value for the natural resonant frequency is displayed below the graph. There are a number of functions that can be performed in this graphics display corresponding to certain key presses, these are:-

'P': Prints out the current screen.
'C': Changes from an amplitude plot to a phase plot or if the phase plot is currently displayed it changes to an amplitude plot.
'D': Draws a theoretical plot of either the amplitude or the phase depending on which plot is currently being displayed on the graph. This appears in a different colour so that it can be compared to the experimental plot.
'M': Allows markers to be displayed on the graph - the user is asked to input the frequency of the low marker and then the high marker. Two vertical dashed lines appear on the graph at these frequencies. These markers will remain on the graph if the plot is changed by pressing the 'C' key.
'F': A dotted vertical line appears on the graph at the frequency of natural resonance (for either amplitude or phase plot).
'ECS': Quits from the graphics display and returns to the main menu.

COMPUTATIONAL PHYSICS - ORBITAL DYNAMICS

Introduction.

In many situations in physics computers can be used to great advantage, e.g. to solve complex analytical equations, to perform long and otherwise tedious calculations, to display results graphically, to control experimental equipment and log and analyse data as they appear. They can be used in an interactive manner, so that the user can see results as they appear, and depending on the outcome can try a slightly different set of input parameters.

Computers are thus a very important tool for the physicist. This experiment is designed to give you an introduction to using computers for solving physical problems - in this case problems in orbital dynamics. The computers available are Acorn Archimedes microcomputers and the language to be used is BASIC. No previous knowledge of computing is assumed, and therefore the first part of the experiment consists of an introduction to BASIC. You will learn how to program the computer, how to input data, and obtain output, both numerical and graphical. Short exercises are given to write programs illustrating these aspects. Once this has been done you will be in a position to use these techniques to investigate:

i) aspects of orbital dynamics, with particular application to celestial mechanics,
ii) the attractive power-law force.

Section 1. Introduction to Basic Programming

Note: Your record book should contain listings of all the programs you write, and printouts of diagrams where indicated. Numerical answers should be given where asked for.

a) Getting the computer to show your results

The PRINT command displays the output from your program as numbers or messages on the screen. The following program tells the computer that a variable A is to have the value 5 (line 10), and then the value of A is to be printed on the screen. Log on to the Econet and click on the Basic icon at the bottom of your screen. You will enter the Editor for preparing programs, with the flashing cursor waiting for you to type in line 10. Type in the program, pressing the Return key at the end of line 10.

```
10 A=5
20 PRINT A
```

If you make a mistake when you are typing a line, you can correct it by using the Delete key, which takes you backwards along the line, deleting characters as it goes. To modify a line on the screen use the arrow keys to move the cursor onto the line and add or delete characters as required. Then press Shift-F4 to leave the Editor and enter BASIC where you see the > sign followed by the cursor, and press F2 to run your program. (See section h: Useful hints.) If the number 5 does not appear, ask a demonstrator.

Press F1 to return to the editor. Move the cursor onto line 20, press Return and add the following lines

```
30 B=A*6+4
40 PRINT "B=";B
```

Note that BASIC assumes priorities for multiplication (*), division (/), addition (+) and subtraction (-). Multiplication and division are performed first, before addition or subtraction. Thus the statement above is strictly (A*6)+4 but you don't need the brackets. If you wanted A*(6+4) you would include the brackets.

When you run your program, line 40 prints a message B= as well as the value of B.

Then type PRINT "A=";A,"B=";B

The computer remembers the values of A and B even after the program has ended.

Now add a line

```
50 C=29
```

and print A. The computer forgets all values when you modify the program. RUN it and try again, and also print C.

b) Saving and Loading Programs

Finally, save your program on the floppy disc. Enter the editor by pressing F1. Press F3 to display a "save" box and type a name such as PROG1 followed by Return. Return to the Desktop, (Shift-F4, then F4), and you will see that your directory viewer contains a file PROG1. Enter the Editor again. Your program has disappeared, but you can load it again by pressing F2 and typing PROG1.

c) Input

It is often necessary for you to supply numerical information to your program. This can be done with the INPUT statement. Type NEW to remove your old program, then type in the following BASIC program.

```
10  INPUT A
20  REM TERMINATE IF A IS LESS THAN 0
30  IF A<0 STOP
40  B=5*A
50  PRINT "A=";A,"B=";B
60  GOTO 10
```

The first line INPUTs a value for the variable A. It does this by writing a ? sign on the screen and waiting until you type a number followed by Return. Line 20 is a remark which is ignored by the computer but acts as an indicator of what the program is doing at a particular point. You should use REM statements frequently throughout any program you write - it helps you to remember what is happening! Run the program, typing in a number whenever you see the ? prompt.

The second line is a conditional statement used to stop the program. It stops if A is LESS THAN 0

Exercise 1. Write a program to accept three numbers representing a length in yards, feet and inches, and print the corresponding length in metres (1 foot = 12 inches, 1 yard = 3 feet, 1 metre = 39.27 inches).

Note: To exit from a program which is running press the key marked Esc (escape).

d) Loops

It is very common to want to repeat a set of operations for a sequence of values of a parameter. For example, sum the series 1+2+3+4+ .. +10. Type in

```
10 ASUM=0
20 FOR I=1 TO 10
30 ASUM=ASUM+I
40 PRINT "STEP ";I,"SUM=";ASUM
50 NEXT
```

Here ASUM is the current value of the sum. At line 10, the starting value is set to 0. Line 20 is a FOR loop which sets I to 1, and executes all the instructions up to the first NEXT statement it encounters (line 50). The computer then chooses the next value of I (2), repeats the instructions from 20 to 50, then does the same with I=3, and so on until I is 10. At line 30, the value of ASUM is increased by I, and ASUM takes on this new value. At a particular time, a variable such as I or ASUM has a definite value, but this value may be different at a later time. RUN the program and make sure it gives the correct answer. Change line 20 to

```
20 FOR I=1 TO 10 STEP 2
```

and run the program. What happened here? Ask the demonstrator if in doubt.

These calculations can also be done using a WHILE...ENDWHILE construction

```
10 ASUM=0
20 I=0
30 WHILE I<10
40 I=I+1
50 ASUM=ASUM+1
60 ENDWHILE
70 PRINT"ASUM=";ASUM
```

Exercise 2. What is the sum of all the integers from 1 to 100?
What is the sum of all the even integers from 2 to 100?

e) Conditional Statements

There are many occasions on which you want to do something only if a condition is true. Use the last program again. Delete line 30 (move the cursor onto line 30 and press Ctrl-D followed by F12) and replace line 60 by

```
60 IF I<10 GOTO 40
```

and run it. It should give the same answer.

f) Procedures and Functions

A procedure is a set of instructions which form a single program unit. A function is a procedure which returns a value.

```
10 FOR I=1 TO 10
20 A=FNCOSH(I)
30 PRINT A
40 NEXT
50 END
60 DEF FNCOSH(X)
70 Y=EXP(X)
80 Z=EXP(-X)
90 =0.5*(Y+Z)
```

At line 20, the computer meets the function FNCOSH and goes off to line 60 to calculate its value. At line 90 the calculation of FNCOSH is completed and the computer returns to line 20 where the value of the function is assigned to A. Run the program to calculate values of cosh(I).

g) Graphics

The screen is divided up into a grid of points 1280 horizontally by 1024 vertically. Each point may be light or dark. Imagine that you are drawing lines on the screen with a pencil. The position of the pencil point is termed the graphics cursor. There are only three graphics commands you really need:

	MODE 0	to initiate graphics,
	MOVE X,Y	to move the graphics cursor to (X,Y).
and	DRAW A,B	to draw a line from the current position of the cursor to (A.B). The cursor will be left at (A.B).

Type

```
MODE 0
MOVE 500,500
DRAW 600,600
```

and see what happens.

Finally, try this:

```
10 MODE 0
20 MOVE 0,0:DRAW 0,1024:      REM Y-AXIS
30 MOVE 1024,512:DRAW 0,512:  REM X-AXIS
40 FOR X=0 TO 4*PI STEP PI/10
50 Y=SIN(X)
60 DRAW 50*X,512+100*Y
70 NEXT
```

Describe what you see. Press the Print key to draw your graph on paper.

h) Useful Hints

i) To obtain a printout of a program you have written, press F3.
ii) When you want to clear the screen type CLS.
iii) Further information on useful commands etc. are given in the BASIC Handbook which is available in the laboratory.

Special Keys

Editor F2 Load a program.
F3 Save a program.
Shift-F4 Return to BASIC.
Cntl-F5 Shows the action of all the function keys.

Basic
F1 EDIT - enter the editor.
F2 RUN - run the program.
F3 LIST - print your program on paper.
F4 QUIT - leave BASIC and return to Desktop.
HELP. Lists all the BASIC keywords (Note the .).
HELP PRINT gives brief help on keyword PRINT (or any keyword which you type instead of PRINT).
The print key gives a screen dump of your display.

Section 2. Celestial Mechanics.

1. The orbit of a planet in the gravitational field of the sun is an ellipse with the sun at one focus. The equation of an ellipse in polar co-ordinates is

$$r = ro(1 + e)/(1 + e\cos\theta)$$

Here e is the eccentricity and ro is the value of r at perihelion, the position of closest approach to the sun.

Write a program to draw planetary orbits on the screen. The sun should be at the centre of the screen (640,512). Use a function FNR(R0,EPS.THETA) to evaluate r. Start with ro = 200 e = 0.5, then try various values of ro and e. Obtain a screendump to put in your laboratory notebook.

The position of the sun should be indicated by including in the program lines to draw a small box at the correct position of at least 5 units square.

Draw the orbits of Mercury, Venus, Earth and Mars on the screen. In the table below. distances ro are given in Astronomical Units. the mean distance of the Earth from the Sun. and you will have to scale these distances to get your diagrams to fit on the screen (e.g. multiply by 200) Describe what you see in your lab book. and printout one or two examples.
Data

Planet	ro(AU)	eccentricity	period (years)
Mercury	0.307	0.206	0.214
Venus	0.718	0.007	0.615
Earth	0.983	0.017	1.000
Mars	1.382	0.093	1.881

2. Kepler's law of areas states that the radius vector from the sun to the planet sweeps out equal areas in equal times. This can be used to relate changes in angle ($d\theta$) to changes in time (dt): $d\theta = dt\left(\frac{S}{r^2}\right)$. (S is a constant.)

Write a program which shows how the speed of a planet varies as it orbits the sun. This can be done by using the following operations:

```
        Initialise variables.
        (Use EPS=0.5, S=4000, T=0, THETA=0, R0=200, DT=1)

WHILE T<5000
        Increment T
        Calculate DTHETA, the change in THETA
        Increment THETA
        Calculate the new value of R
        Plot the new point
ENDWHILE
```

To increment T, simply write T=T+DT.
Calculate R from your FNR(R0,EPS,THETA) of exercise 2.

What do you notice about the speed of the planet when it is
a) closest to the sun, and
b) farthest away from the sun?

3. (If time permits - for students with computing experience)
Using the data in problem 2, write a program to show the simultaneous rotation of two (or more) planets around the sun. You may assume that the planets move in the plane of the screen. The relative values of S can be found from the total area of the orbit divided by the period. The total area is $A = \pi ab$ where $a = ro/(1-e)$ and $b = ro(1+e)$. Calculate A divided by the period. Then set Mars (say) to have a value of S = 4000, and scale the other planets accordingly. Then use these values of S in your program.

Section 3 Investigations of the Attractive Power Law Force (Reference Fowles)

In this section, we study the motion of a particle moving under the influence of a force

$$F = -K\,r^{\alpha}$$

We want to investigate the nature of trajectories resulting from different values of a. Closed circular orbits are always possible if the initial velocity v is at right angles to the line joining the particle to the centre of force, and

$$\frac{Mv^2}{r} = Kr^{\alpha} \quad \text{i.e. } v^2 = \frac{K.r^{\alpha+1}}{M}$$

We want to study the stability of such circular orbits.

Return to the Desktop, click on your "Utilities" directory and double-click on "Orbits". The program allows you to launch a particle of mass M from a given point (X,Y) with a given velocity (VX,VY) in a central field. The initial conditions are determined by lines 10 to 110 of the program which assigns the values.

M=1; Alpha=-2; K=1; X=1; Y=0; VX=0; VY=1.1.

To change parameters simply rewrite the appropriate line. When you have run the program and seen sufficient length of trajectory to understand the shape of the orbit, press Esc to exit. Note that in this program the time taken between plotting adjacent points does not reflect the speed of the particle, unlike the previous exercise. You will find for some plots where the particle lies close to the centre, the program is slow to plot. Allow sufficient time to observe the full trajectory.

a) First, use the above values to convince yourself that the program works for the inverse square law.

b) Change Alpha to -2.5, and VY = 1.01. Run the program and describe the trajectory. Repeat with VY=0.95 and VY=0.7.

c) Change Alpha to +1. Run the program with VY=1.5, VY=1 and VY=0.5. Describe the motion. Is it what you would expect ?

d) The stability of circular orbits.

You will have gathered by now that VY=1 always gives a circular orbit. (Why ?)
Describe the trajectories resulting from the following choices of parameters:

Alpha=-4; VY=1.01, and VY=0.99.

Alpha=-2.5; VY=1.01 (see b) above), and VY=0.99.

Are your results in agreement with the known conditions for the stability of circular orbits ?

N.B.: Sketch the forms of the orbits in your lab book for all the examples tried.

APPENDIX-C (PAGES 260-267)

PRE-LAB USED DURING PHASE-I

APPENDIX-C

THE PRE-LABS PREPARED AND USED DURING PHASE-I ACADEMIC SESSION 1994-95.

PRE LAB: DIFFRACTION AND INTERFERENCE, USING A LASER

Pre lab:

The following preparatory work for this experiment should be **done before you come to the lab.** Your demonstrator will check that this has been done.

What does a laser do ?

The unique characteristics of light produced by laser make it suitable for many applications, for example: (1) welding, (2) cutting, (3) drilling, (4) tracking, (5) precision length measurement, (6) velocity measurement, and (7) medical etc.

Why use it in this practical ?

The characteristics of laser light make it ideal for the experimental study of diffraction and interference phenomena of light waves.

What is the point of this experiment ?

You will work with the diffraction and interference pattern from a single slit and from many slits. You will measure the wave length of light from the helium neon laser. You will study some of the properties of a hologram.

How does it works ?

Read the description in the manual, and the relevant pages of Jenkins and White.

What will I be doing ?

Obtain the diffraction pattern from a single slit and use it to measure the wave length of the laser light. Do the same thing with several slits and gratings and compare your results with those obtained with the computer package **diffract.** Then investigate the properties of holograms.

What should I know before I begin ?

-You should be familiar with the principles of the operation of a laser.

-The characteristics of laser light which make it suitable for this experiment.

-You should be sufficiently familiar with the ideas of diffraction and interference to understand the experiment.

-How a hologram is produced.

-(See Jenkins and White).

POST LAB: USING A LASER

You should do the following work after you have written the experiment in your record book.

1. If you look at a strong point source of light (Not a laser) through the fabric of a handkerchief, you will see an unusual pattern. Explain how it arises. What does it tell you about the cloth ? Write your explanation.

PRE LAB: MECHANICAL OSCILLATOR AND RESONANCE

Pre lab:

The following preparatory work for this experiment should be **done before you come to the lab**. Your demonstrator will check that this has been done.

What should I expect to see in this experiment ?

You will see for yourself the behaviour of a resonating system especially how the amplitude of vibration increases dramatically when the frequency of an applied force matches the natural frequency of the system. You will discover how the phases of the oscillation and applied force are related. You will see how damping affects the motion of a vibrating system.

What will I be doing?

You will use the vibrating bar to plot a graph of amplitude versus the frequency of the applied force. This will show a resonance.

You will use an oscilloscope to display two sine waves, one for the motion of the bar and one for the applied force. You can find the phase difference from the traces on the oscilloscope.

What equipment will I be using ?

Read the description in the lab manual.

What should I know before I begin ?

-What is meant by resonance?

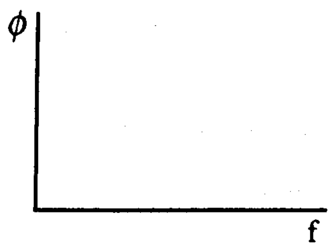
-What is meant by phase and phase difference ?

-How to recognise a resonance ?

-How to damp the motion of the vibrating bar ?(See French: Vibration and Waves).

-Complete the graphs below by drawing typical curves of amplitude(A) vs frequency

(f) and phase difference (ϕ) vs frequency (f).



POST LAB: RESONANCE

You should do the following work after you have written the experiment in your record book.

1. When water is irradiated with the higher energy end of the infrared spectrum, it absorbs strongly at a wave length of about $3.0\text{x}10^{-6}$m (~$10^{14}H_z$) and hardly any where else. Why should this be so ? If heavy water D_2O is used, the frequency absorbed moves to another fixed value why ? Is water vapour a possible greenhouse gas ?

2. Are coloured objects still coloured even in the dark ? Give a reasoned explanation for your choice.

3. How are the oscillations set up in a car's suspension system overcome (at least partially) ?

4. How does a flute (chanter, tin whistle, recorders) work, or any other musical instrument for that matter ? How is a drum damped ? Write a paragraph explaining this to a layman.

PRE LAB: X-RAYS

PRE LAB:

The following preparatory work for this experiment should **be done before you come to the lab.** Your demonstrator will check that this has been done.

What information can be obtained from X-rays ?

X-rays are used to determine the structure of crystals and molecules.The spectrum of X-rays emitted by an atom gives information about the structure of that atom.

Why use X-rays in this experiment ?

You are going to measure the inter atomic (or ionic) distances in a solid. To do this you have to use radiation, the wavelength of which is similar in size to the distances being measured. X-rays have a wavelength of suitable size.

What will I measure ?

(1) You will measure the distance between planes of ions in crystals of KCl and NaCl.

(2) You will obtain a spectrum of the X-rays emitted by Copper and study the absorption of X-rays by Copper and Cobalt foils.

How does the spectrometer works ?

Read the description in the lab manual. X-rays from the Copper anode are passed through the slit to form a thin parallel beam, while X-rays striking the material on either side of the slit are absorbed. The beam of X-rays is then scattered by the layers of ions in the crystal. The intensity of scattered X-rays varies rapidly with the angle of incidence θ. When the Geiger counter detects an X-ray it gives out an electrical pulse. The rate meter is activated by these pulses and gives a reading in count/second.

What will I be doing ?

-Using the crystals of LiF, plot a spectrum of counting rate against angle.

-Knowing the interionic spacing in LiF determine the wavelength of the K_α and K_β lines of copper.

-Measure the interionic spacing of KCl and NaCl.

-Obtain X-ray absorption spectra for Nickel, Copper and Cobalt.

What should I know before I begin ?

You should know:

-The value of interionic distance d_1 for LiF (Calculate it as described in the manual).

-What is meant by the term **spectrum.**

-The Bragg conditions. (See Walton."Three phases of matter").

-What is meant by the term **angle of incidence** in optics and in X-ray diffraction, and how do their meanings differ.

POST LAB: X-RAYS

You should do the following work after you have completed the experimental work in the lab.

1. Using a model check that some planes have equal numbers of positive and negative ions and so all such planes should interact similarly with X-rays. Now move the model around and find planes where all the ions are all positive and all negative. In the case of NaCl which layers will interact more with X-rays and why?

2. Use 4cms wave apparatus to convince yourself that Bragg's equation is true.

3. Look at the powder photographs supplied. Can you see any pattern in terms of line intensities for crystals of identical packing e.g. NaCl and KCl but with different patterns for NaCl vs CsCl. Look at the powder photograph for NiO. What is its packing ? Report your answers.

PRE LAB: ORBITAL DYNAMICS

Pre lab:

The following preparatory work for this experiement should be **done before you come to the lab.** Your demonstrator will check that this has been done.

Why use a computer ?

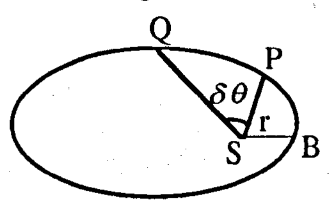
Some of the problems you meet in this experiment do not have analytical solutions but can be solved very easily by computer.

What will I accomplish with this experiment ?

You will generate a computer demonstration of the motion of planets around the sun showing how their positions vary with time.

You will use an existing computer program to study the motion of a particle in a central field $F \propto r^{\alpha}$. There is no general analytical solution for this problem.

What is the theoretical background ?



Kepler's first law states "The orbit of a planet around the sun is an ellipse with the sun at a focus". In polar coordinates, the equation of an orbit is:

$$r = r_o \frac{1+e}{1+e\cos\theta} \quad \text{where the sun is at the origin } (r=0).$$

Here e is the eccentricity and r_o is the distance of closest approach of the planet to the sun (SB in the diagram) while occurs when $\theta = 0$.

This equation tells us which points are visited by the planet but does not tell us the position of the planet at a given time. For that we need Kepler's second law.

Kepler's second law states that the area δA swept out in a time δt by the line from the sun to the planet is proportional to δt. It does not depend on the position of the planet in its orbit. If $\delta\theta$ is small the area of triangle SPQ is

$$\delta A = \frac{1}{2} r^2 \delta\theta \cdot$$

let $\delta A = R\delta t$ where R is constant

$$\frac{1}{2} r^2 \delta\theta = R\delta t \;\therefore\; \delta\theta = \frac{2R}{r^2}\delta t = \frac{S}{r^2}\delta t \qquad \text{where } S = 2R$$

If we know the polar coordinates $(r\theta)$ of the planet at time t, we can calculate the small increase in θ in a short time δt:

$$\delta\theta = \left(\frac{S}{r^2}\right)\delta t .$$

At time $t + \delta t$, the new value of angle is $\theta' = \theta + \delta\theta$.
The value of r is $r' = r_\circ \dfrac{1+e}{1+e\cos\theta'}$
The coordinates of Q are $(r'\theta')$, which is the position of the planet at time $(t + \delta t)$

We can then use these new values of angle and distance to repeat the above sequence of calculation, and find the position at time $[(t + \delta t) + \delta t]$, and so on.

What am I going to do ?

-Write a few programs to extend your computing skills (read the description in the manual).

-Draw ellipses on the computer (planetary orbits).

-Display the time development of a planet in its orbit.

-Investigate force laws for which analytical solutions do not exist.

What should I know before I begin ?

To check that your programs give the correct answers, you should calculate the following.

-The sum 1+2+3+4+.........+10 ?

-The sum 1+2+3+............+99+100 ?

APPENDIX-D (PAGES 268-270)

ADVICE TO DEMONSTRATORS

APPENDIX-D

ADVICE TO DEMONSTRATORS

The main purpose of the research work, going on in the physics II lab, is to improve the teaching-learning strategies. You are requested, to extend your co-operation and consider the following points during lab hours, which will be helpful to consolidate the research achievements.

1. Please allow the students to do the post-lab work, for the last experiment they did, **before** they start the new experiment.
2. Please ask the students about their preparation, within the context of the information provided in the pre-lab sheet, if they have been provided with the pre-lab sheet for the experiment.
3. You will receive a questionnaire, about every experiment for each group. Please complete it, and return to the researcher (Mr. Tanvir Uz Zaman), as soon as possible after the completion of each experiment.

DEMONSTRATOR'S FEED BACK

Experiment ____________ **Week** _____ **Name** __________

The following questions will help us to consolidate the research work, we are doing in the Physics II lab and will help the Department of Physics and Astronomy to improve the lab manual and the teaching and learning methods as well. Please answer these questions carefully.

1. How many students were in your group when you demonstrated? _______
2. How many students in the group did you talk to about their preparation for this experiment? _______
3. How many students had done adequate preparation before they came to the lab? _______
4. How many students understood the purpose of this work when they started the experiment? _______
5. How many students needed help from you during the experiment?_______
6. How many students needed help to set up the apparatus? _______
7. How many students needed help to understand the theory/concepts/laws/principles, related to this experiment? _______
8. How many students were helped by the pre lab during experiment? _______
9. Would it be an advantage to have additional material in the pre lab sheets? _______
10. How many students completed this experiment within the prescribed time?

11. Please give your comments regarding the **pre and post-lab**, used in this experiment. We would welcome suggestion on how they could be improved.

APPENDIX-E (PAGES 271-274)

DEMONSTRATORS OBSERVATIONS AND ADVICE TO STUDENTS

APPENDIX-E

DEMONSTRATOR'S OBSERVATIONS/COMMENTS ON "LASER"

1. I think this is a very good experiment, it has following advantages:

(a) Gave students good training both in measurements technique and in data processing.

(b) get students understand the concepts of Diffraction and interference better.

(c) The experimental contents are rich and systematic.

In general, it is a very good design.

Suggestions:

(a) I think it could be better if the computer program was done before starting the experiment, because the students can attention to some phenomena, e.g. secondary maxima, when they observe the multiple slits.

(b) It would be better, if the manual can list some important points for this experiment.

WEIXIAN PENG

DEMONSTRATOR PHYSICS -II LAB(1994-95) SESSION

DEMONSTRATOR'S OBSERVATIONS/COMMENTS ON "MECHANICAL RESONANCE"

I only started questioning student on the pre-lab quite late on second term as I am only standing on for Professor Owens and was not informed about these pre-labs.

So in all I asked seven people.

Four were enthusiastic for pre-lab.

Three were strongly against.

The against said they simply gave them extra work and never taught them anything, the only possible result was that they did read the pre-lab when they admitted they were quite likely to have not read the lab manual before the session.

They also said it would be better to have a pre-lab where they could see the equipment to get a brief overall of experiment.

The four who liked their pre-lab, said it was helpful to get a summary they could read without being put off by references to equipment they couldn't see. If they were busy the pre-lab was a good way to get on overall idea about the physics that would be involved.

All seven admitted they didn't do the pre-labs very throughly.

six/seven said they liked at least the first part of the experiment (mechanical) because it helped them understand their vibration and waves course.

REBECA CRAWFORD

DEMONSTRATOR PHYSICS-II LAB SESSION 1994-95

DEMONSTRATOR'S OBSERVATIONS/COMMENTS ON "ORBITAL DYNAMICS"

Pre-lab

comments varied, however, they could be separated into three categories.

1. students studied the sheet before lab

   because knowledge of required theory .

   This group thought a pre-lab was useful.

2. Student mislaid/ ignored pre-lab sheets.

   No intention of looking at it prior to lab.

3. Student studied sheet during the lab and realised that it was very helpful.

CONCLUSION:

Excellent idea in theory however, more difficult to implement in practice.

MARGARATE

DEMONSTRARTOR, PHYSICS-II LAB SESSION 1994-95.

ADVICE TO STUDENTS

You should keep in mind the following points regarding the educational research work taking place in the physics II lab:

1. The purpose of this research is to improve your learning and our teaching.
2. You are expected to go through the lab-manual before coming to the lab and to be guided by the Pre-lab sheets, (if provided) for the particular experiment.
3. You will be given pre-lab sheets for 50% of the experiments. For example out of four experiments, you will receive pre-lab sheets for two experiments. The selection of two experiments, for which you get the pre-lab sheets will be at random.
4. The pre lab sheet will be available on the table, just at the entrance on the lab, one week before you start the experiment. Your sheet will have your name on it.
5. At the end of each experiment, you will be asked to complete post-lab sheets. Again the sheets will be available on the entrance table. You should do the post-lab work before starting on the next experiment.
6. After the completion of post-lab work, please return the Sheet (Post-lab:), to the same entrance table or to the researcher

Mr.Tanvir Uz Zaman.

7. In summary, you should check the table at the entrance to the lab every week.

APPENDIX-F (PAGES 275-300)

HIDDEN FIGURE TEST "SHAPES"

APPENDIX-F

HIDDEN FIGURE TEST "SHAPES"

WORDS

ELEMENT SEARCH	
WORD-BUILDING	
A 'FIVERS' CROSSWORD	
CRYPTIC CLUES	
A JIGSAW CROSSWORD	

PICTURES

A PILE OF PAPER	
SQUARES & TRIANGLES	
FLIPPING SHAPES	
PAPER FOLDING	
PATTERNS	
HOW MANY PARTS?	

SHAPES

SHAPES 1										
SHAPES 2										

TOTALS

WORDS TOTAL	
PICTURES TOTAL	
SHAPES TOTAL	
TOTAL SCORE	

AGE GROUP	

SHAPES

This is a test of your ability to recognise simple SHAPES, and to pick out and trace HIDDEN SHAPES within complex patterns..

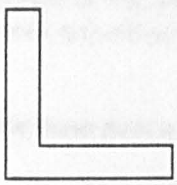
The results will not affect your school work in any way.

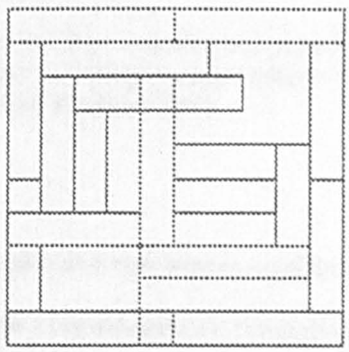
YOU ARE ALLOWED ONLY 15 MINUTES TO ANSWER ALL THE ITEMS.
TRY TO ANSWER EVERY ITEM, BUT DON'T WORRY IF YOU CAN'T.
DO AS MUCH AS YOU CAN IN THE TIME ALLOWED.
DON'T SPEND TOO MUCH TIME ON ANY ONE ITEM.

DO NOT START UNTIL YOU ARE TOLD

LOOKING FOR HIDDEN SHAPES

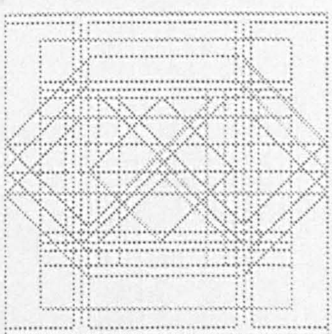
A simple geometrical figure can be 'hidden' by embedding it in a complex pattern of lines. For example, the simple L-shaped figure on the left has been hidden in the pattern of lines on the right. Can you pick it out?





Using a pen, trace round the outline of the L-shaped figure to mark its position.

The same L-shaped figure is also hidden within the more complex pattern below. It is the **same size**, the **same shape** and **faces in the same direction** as when it appears alone. Mark its position by tracing round its outline using a pen.



(To check your answers, open out the flap on the back cover of this booklet.)

More problems of this type appear on the following pages. In each case, you are required to find a simple shape 'hidden' within a complex pattern of lines, and then, using a pen, to record the shape's position by tracing its outine.

There are TWO patterns on each page. Below each pattern there is a **code letter** (A, or B, or C etc.) to identify which shape is hidden in that pattern.

Open out the flap on the back cover of this booklet, and you will see all the shapes you have to find, along with their corresponding code letters. Keep this page flap opened out until you have finished all the problems.

Note these points:

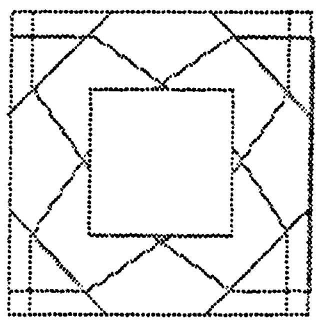
(1) You can refer to the page of simple shapes as often as necessary.

(2) When it appears within a complex pattern, the required shape is always
the same size,
has the same proportions,
and **faces in the same direction**
as when it appears alone.

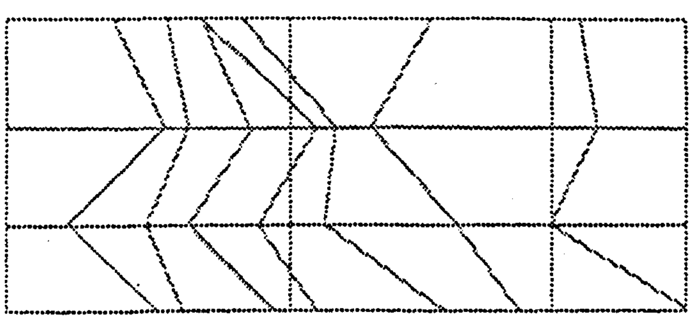
(3) Within each pattern, the shape you have to find appears only **once.**
Trace the required shape **and only that shape** for each problem.

(4) Do the problems in order — don't skip one unless you are absolutely stuck.

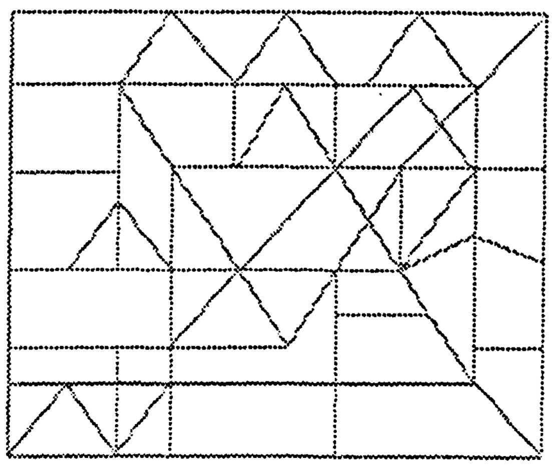
START NOW



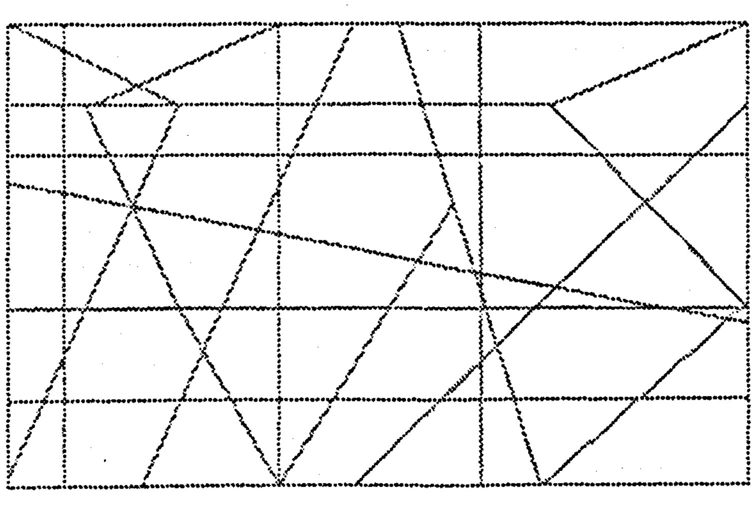
Find SHAPE B



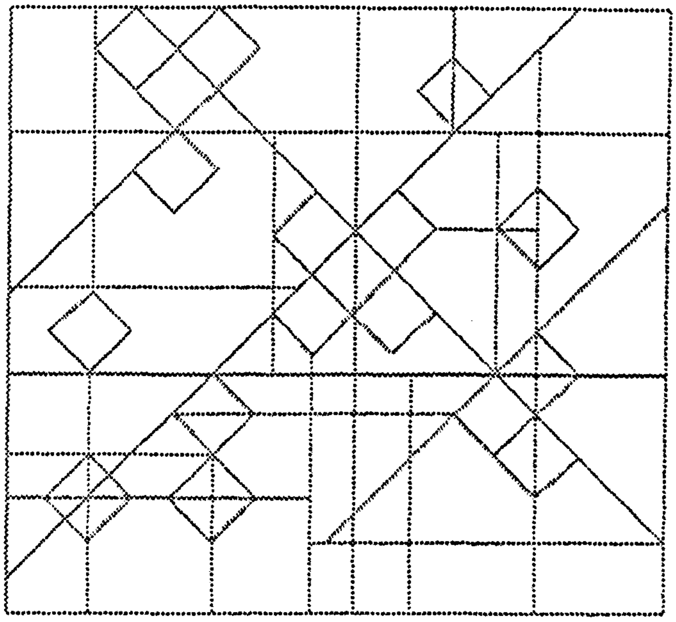
Find SHAPE D



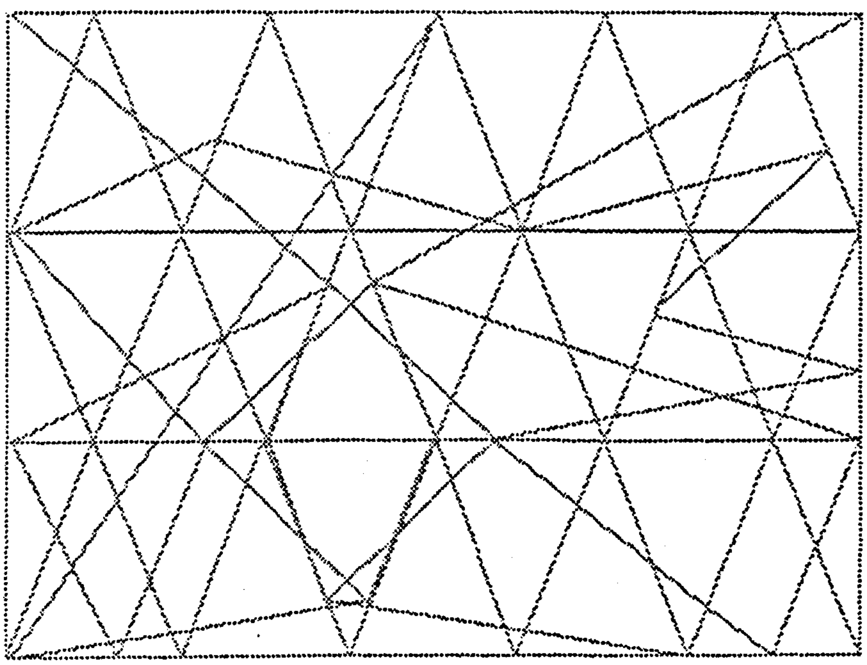
Find SHAPE H



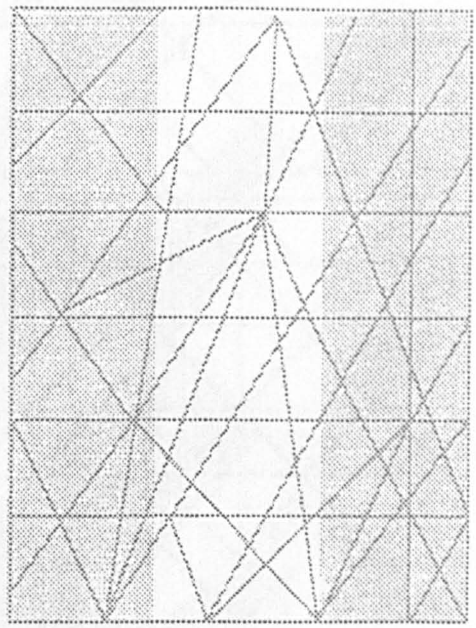
Find SHAPE E



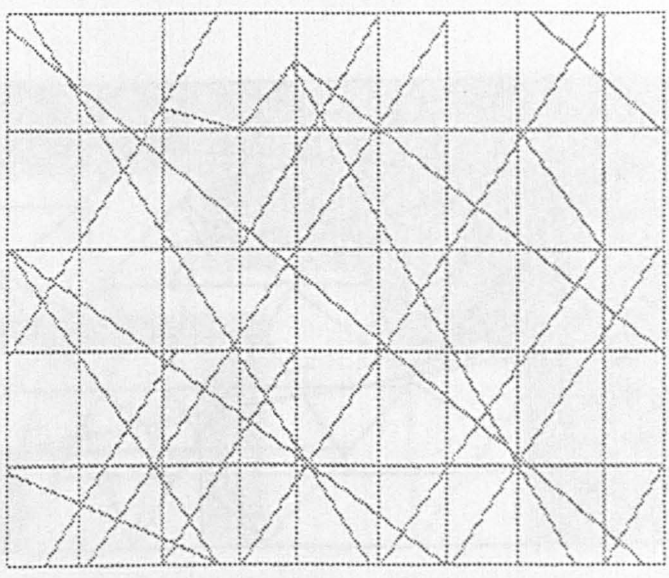
Find SHAPE F



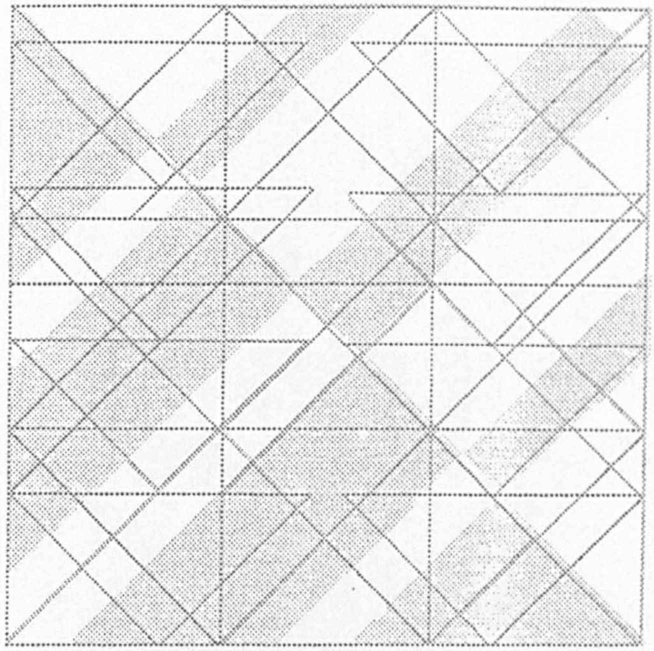
Find SHAPE A



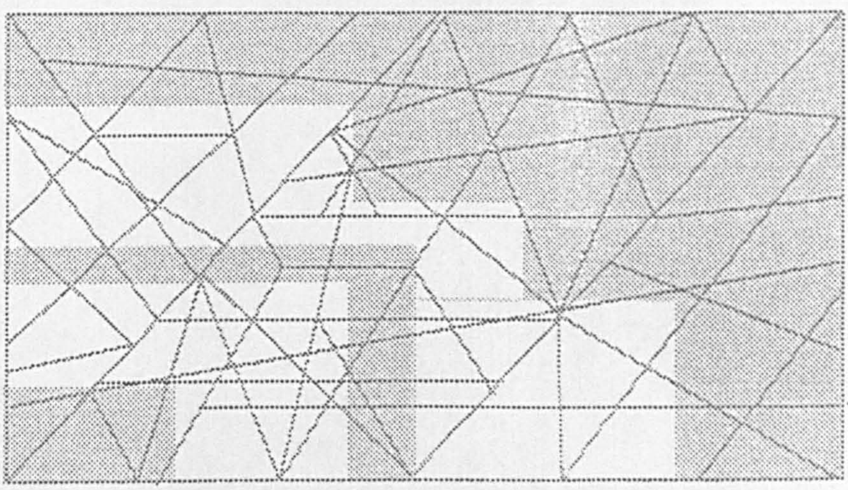
Find SHAPE E



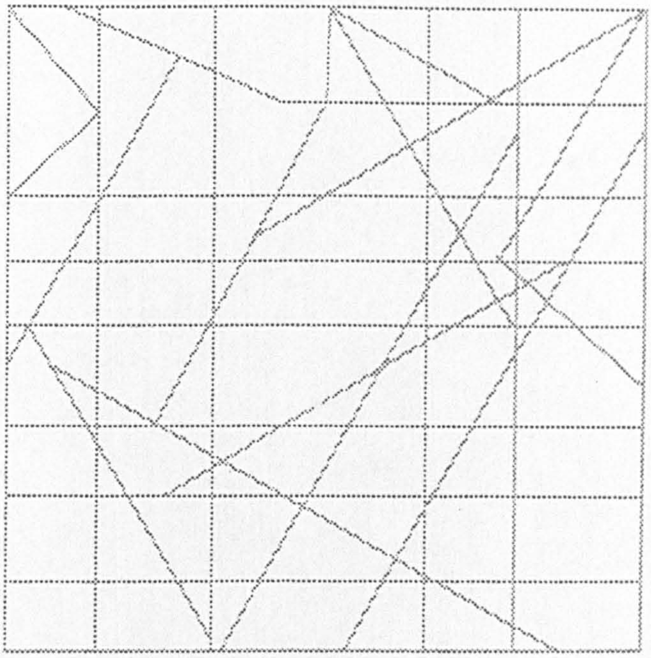
Find SHAPE H



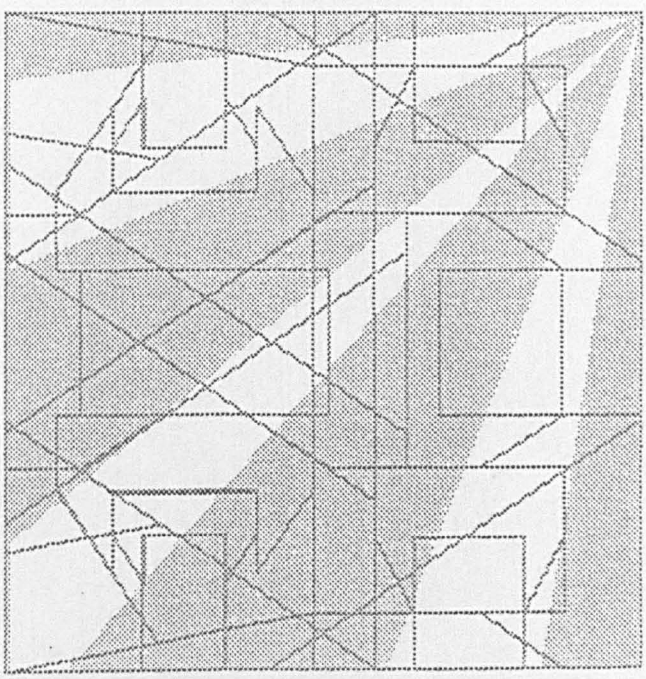
Find SHAPE D



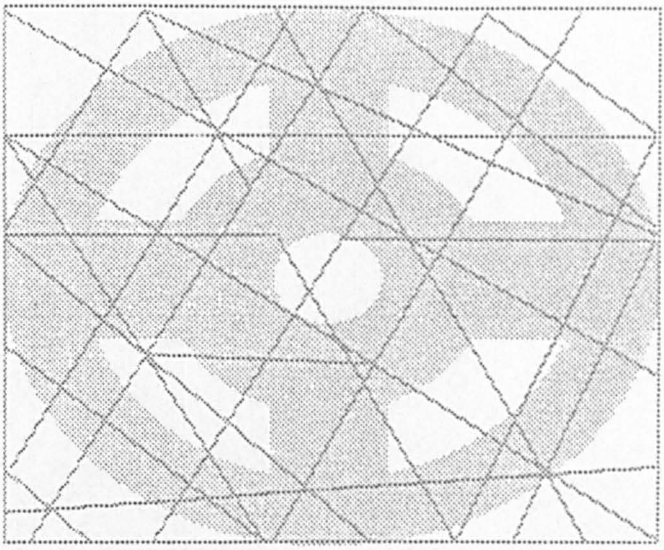
Find SHAPE G



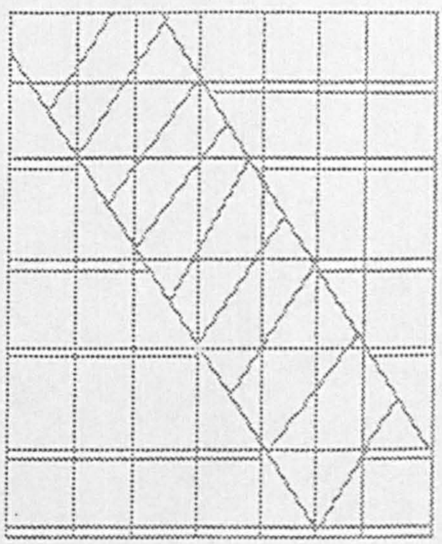
Find SHAPE C



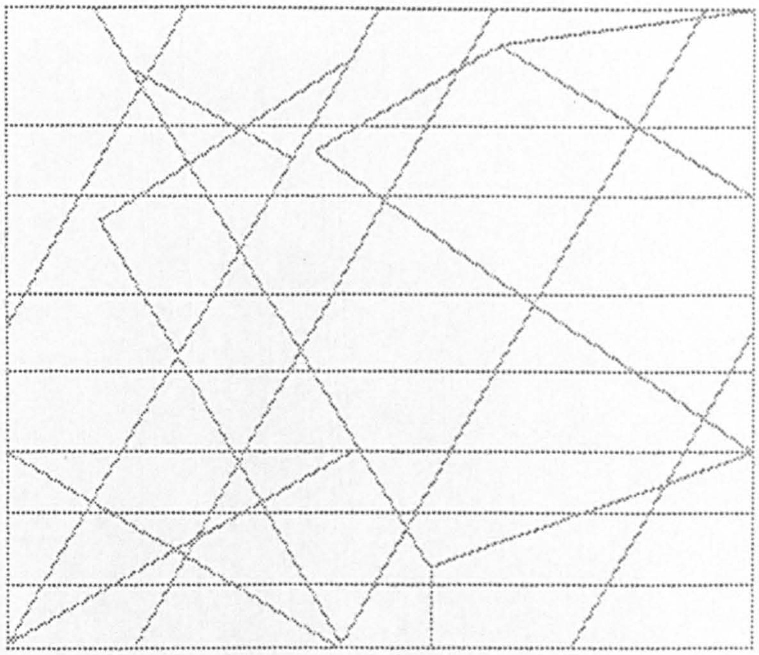
Find SHAPE B



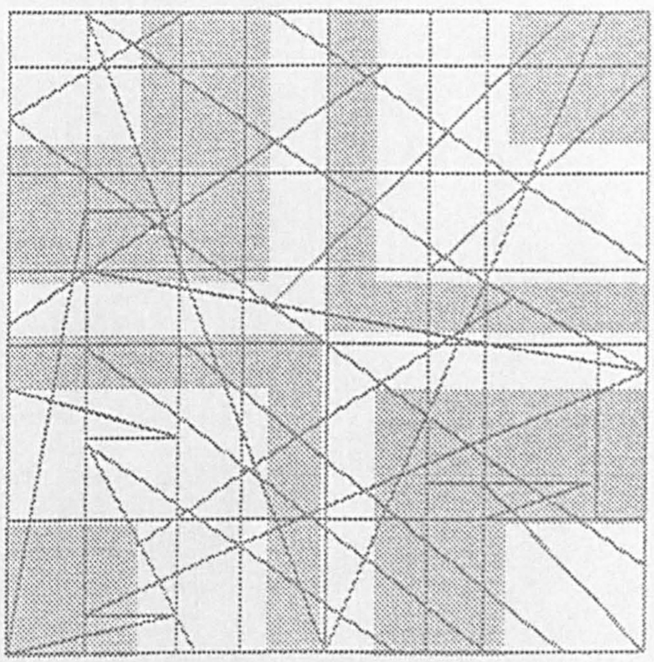
Find SHAPE G



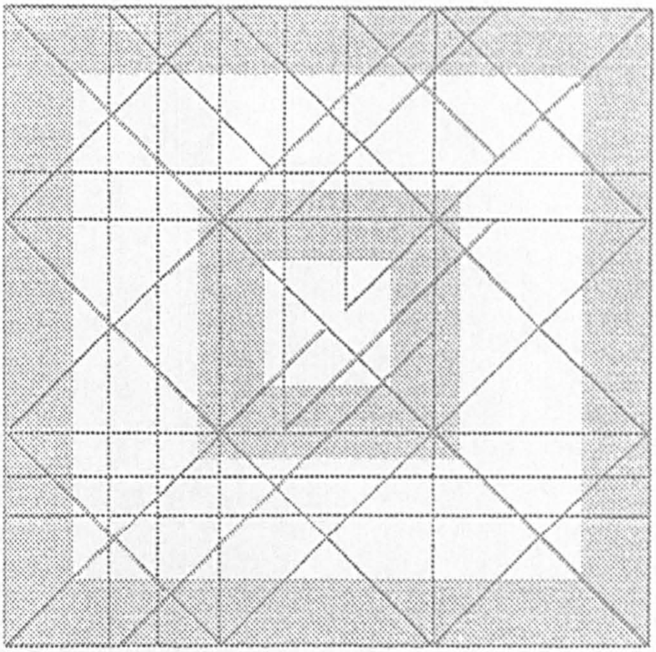
Find SHAPE H



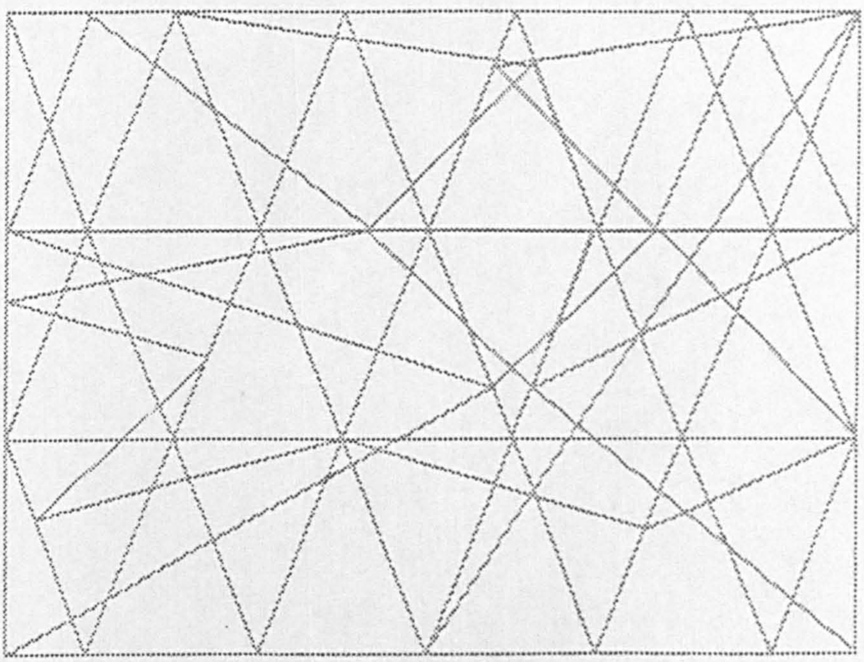
Find SHAPE C



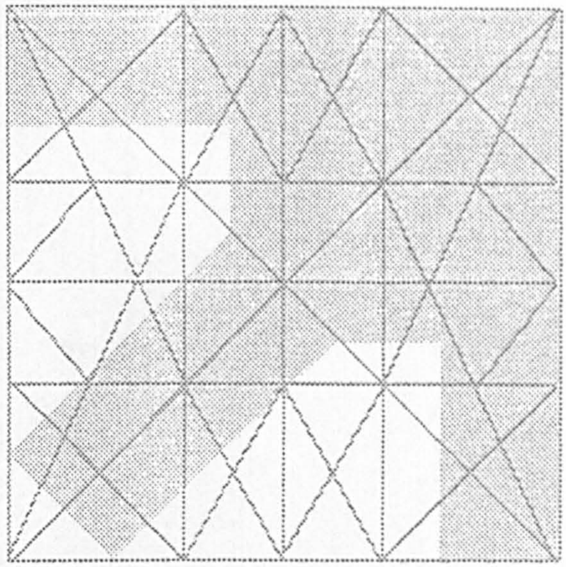
Find SHAPE B



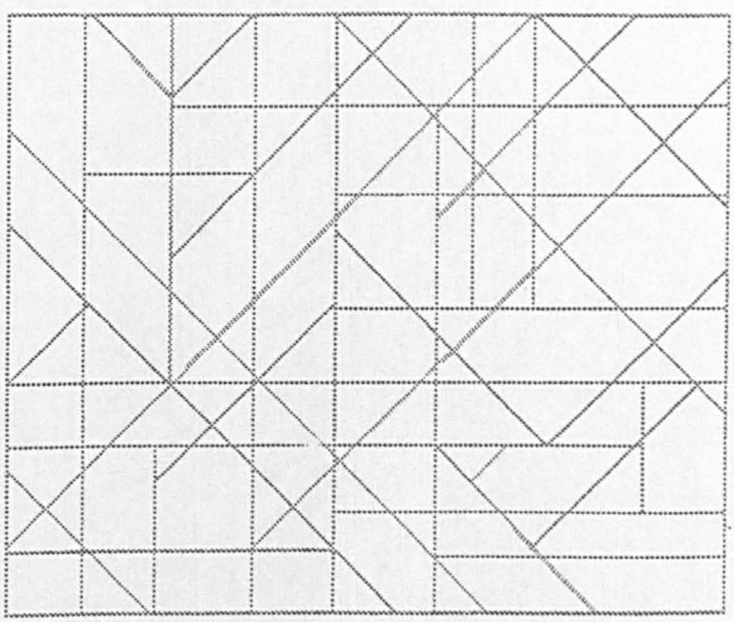
Find SHAPE D



Find SHAPE A

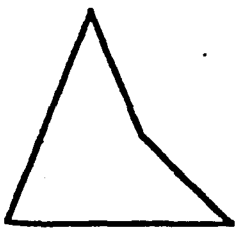


Find SHAPE E

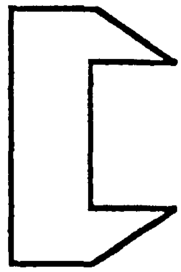


Find SHAPE F

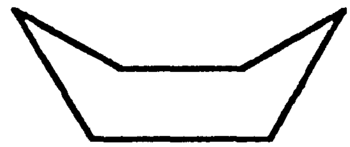
THE SHAPES YOU HAVE TO FIND



A

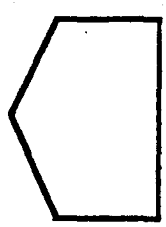


B

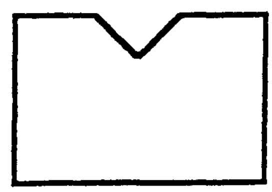


C

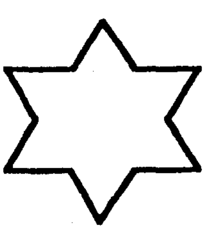
D



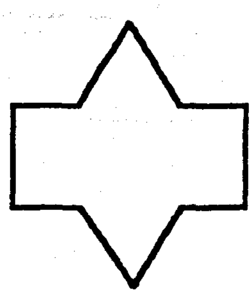
E



F

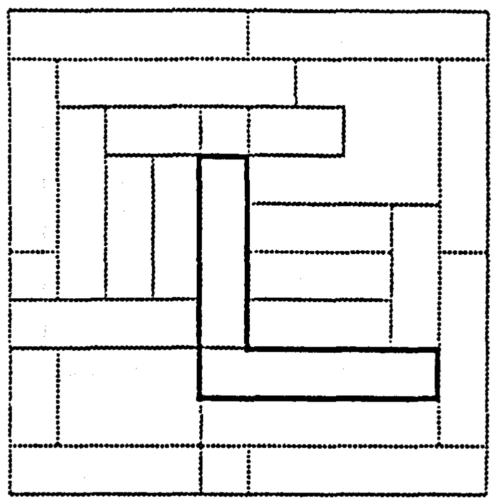


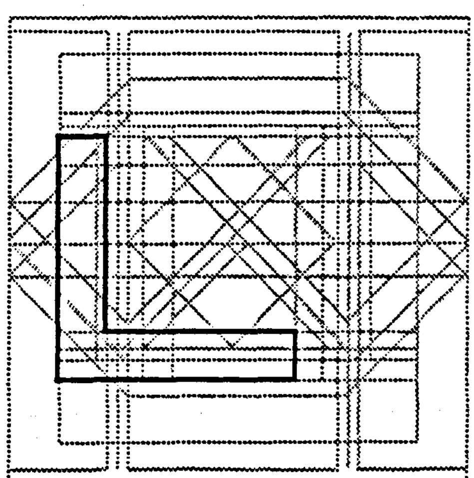
G

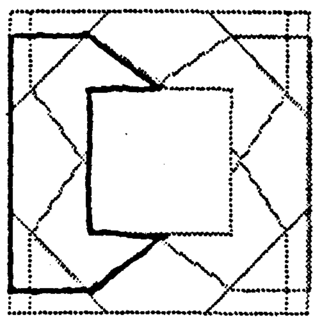


H

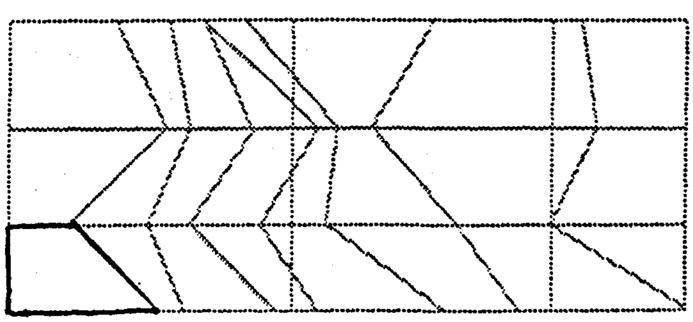
When you have traced both L-shaped figures, the diagrams should look like this :







Find SHAPE B



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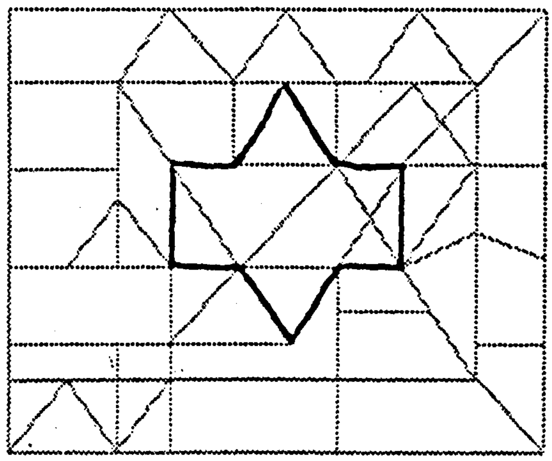

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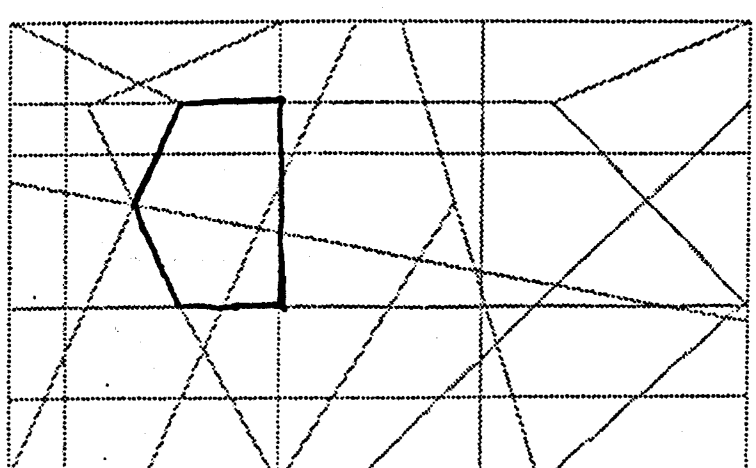
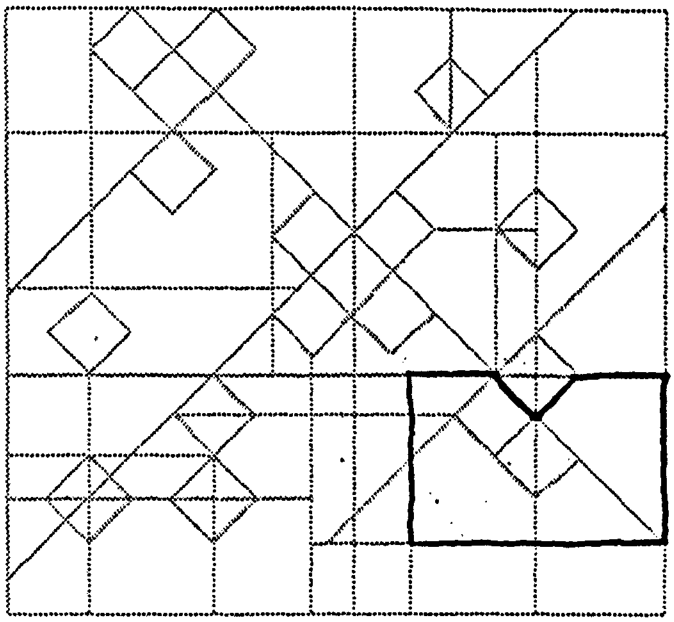


Find SHAPE E



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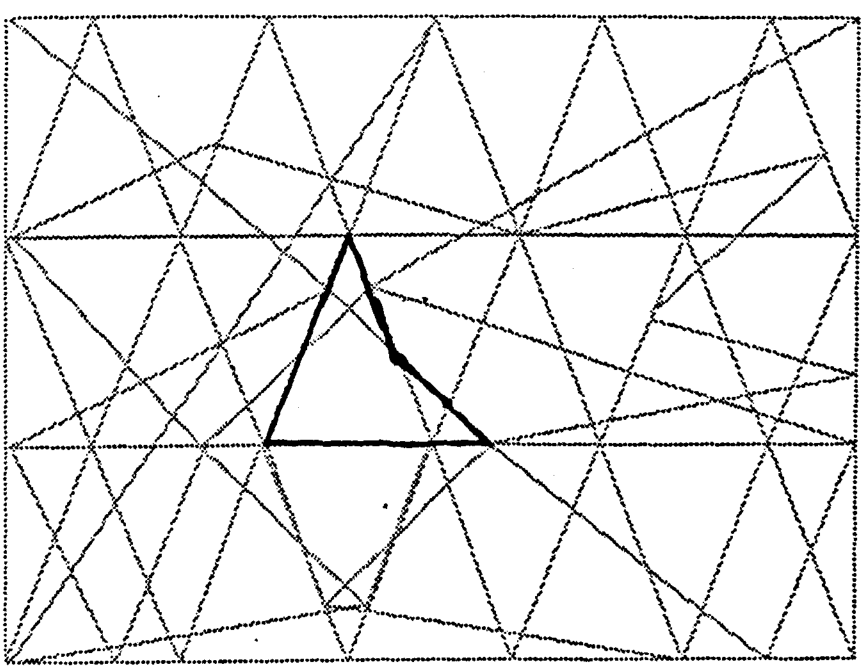

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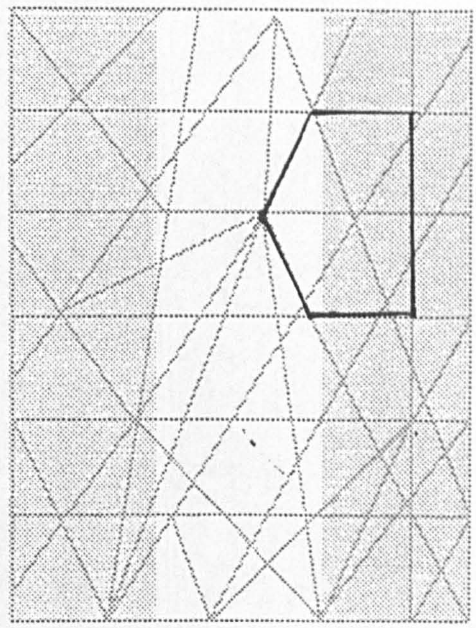

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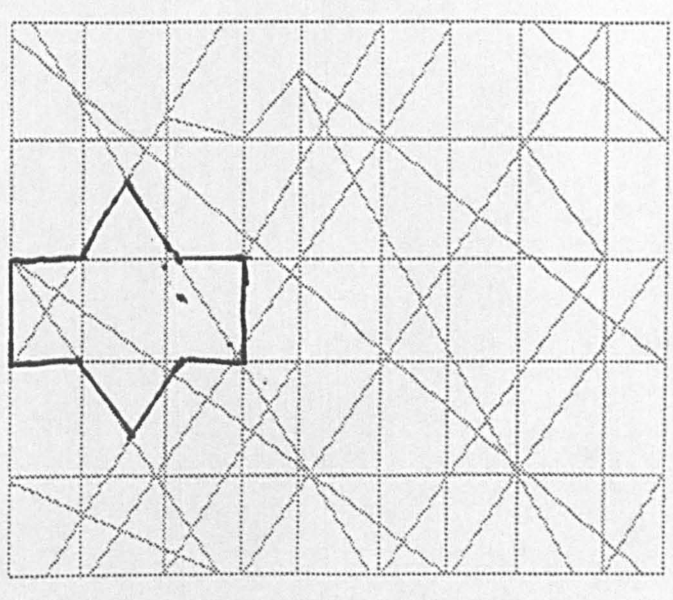

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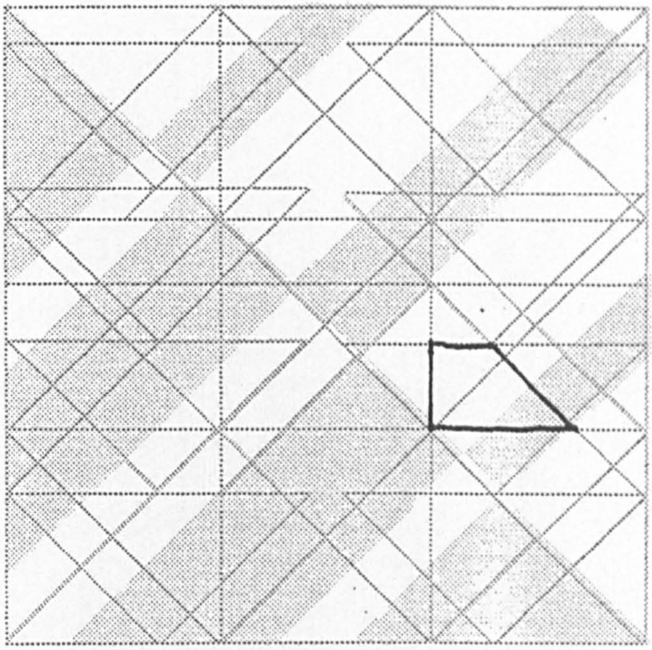

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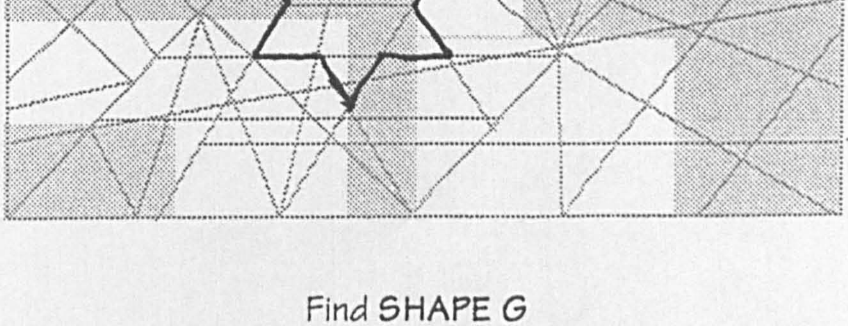
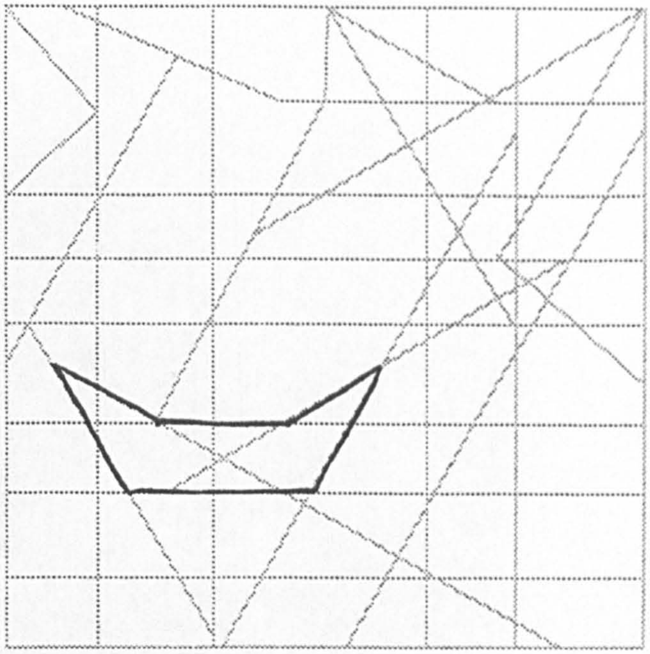
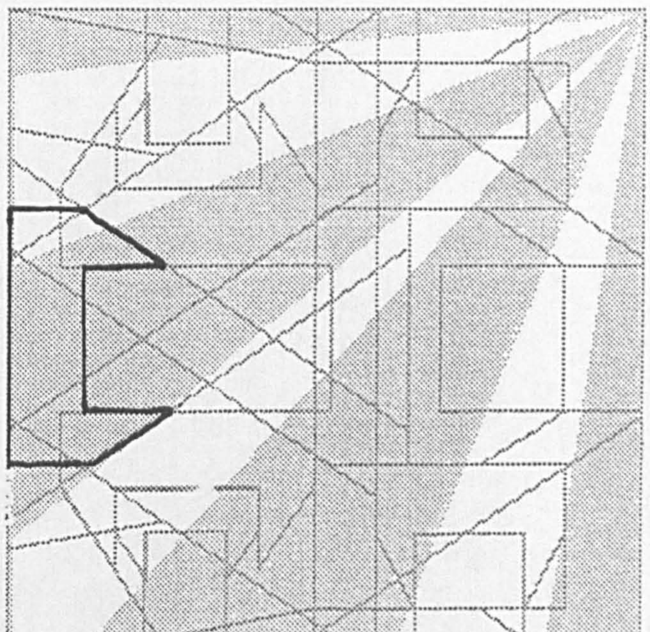


Find SHAPE G



Find SHAPE C



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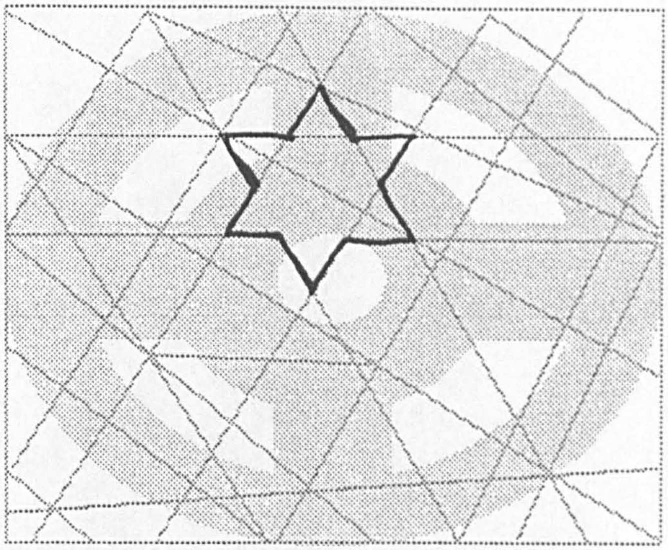

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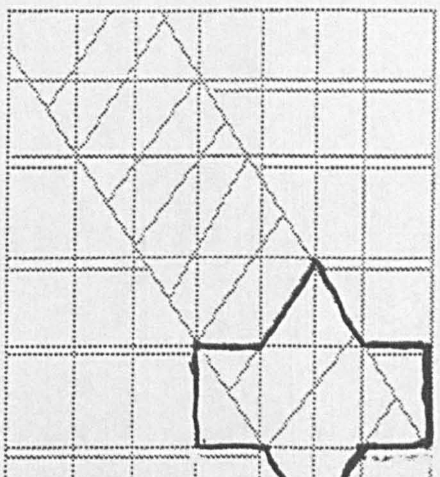

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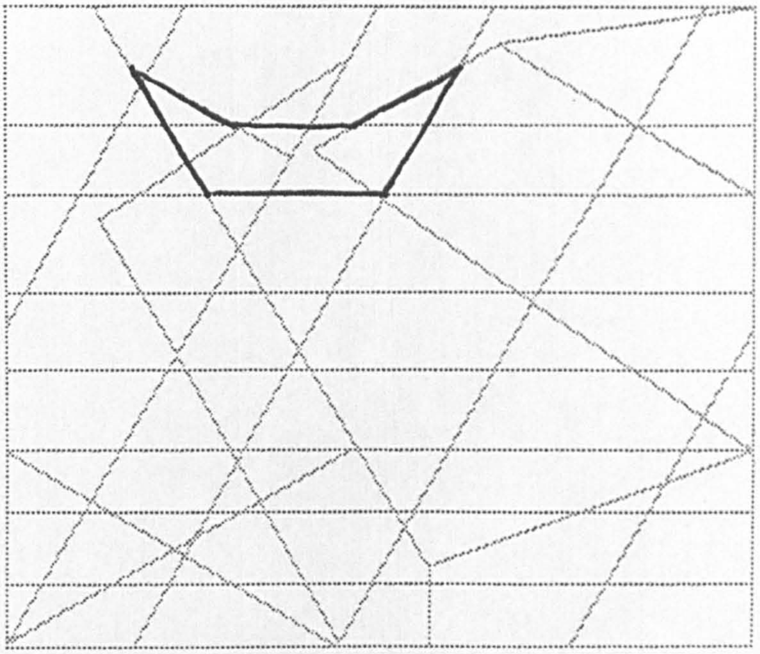

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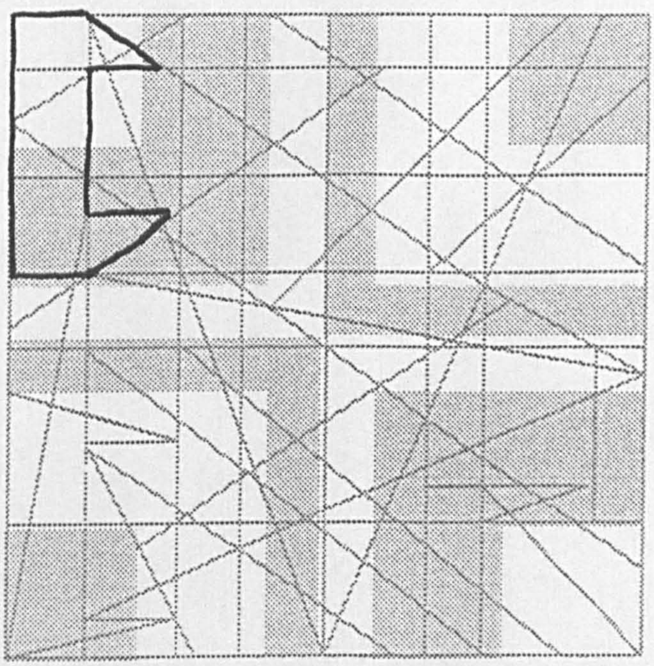

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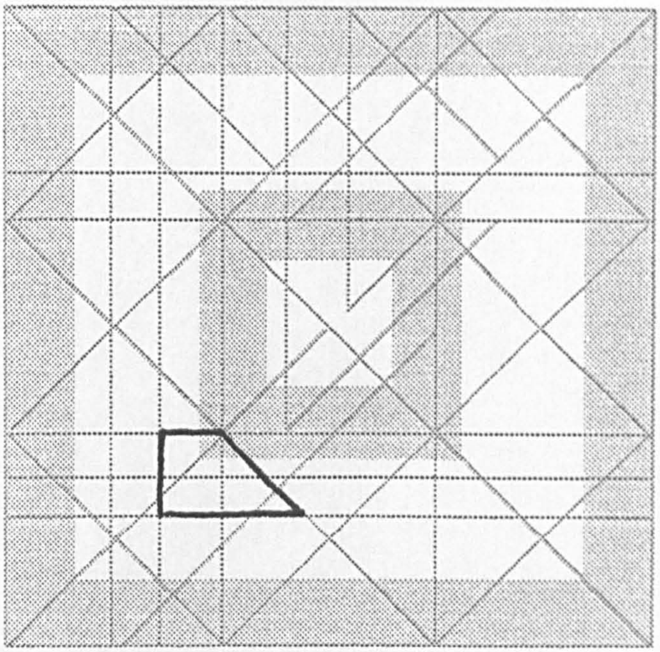

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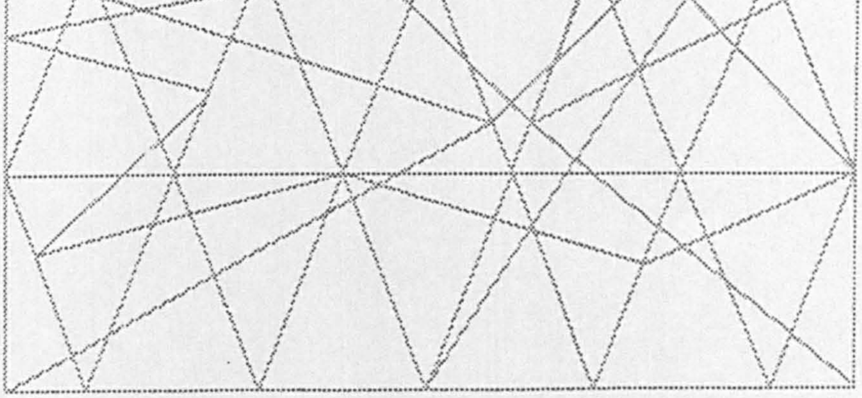
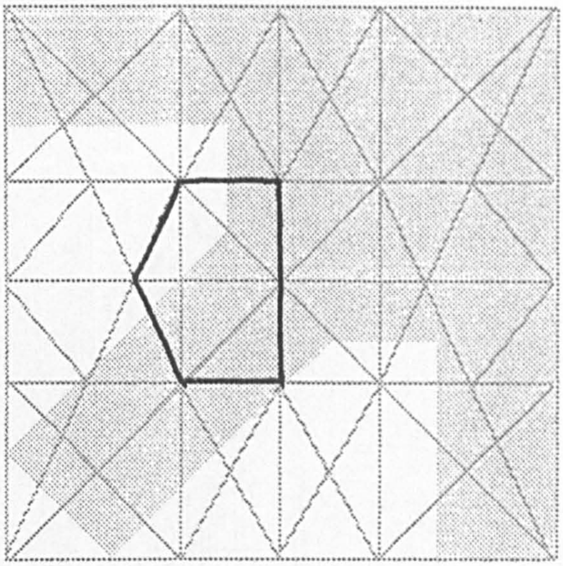
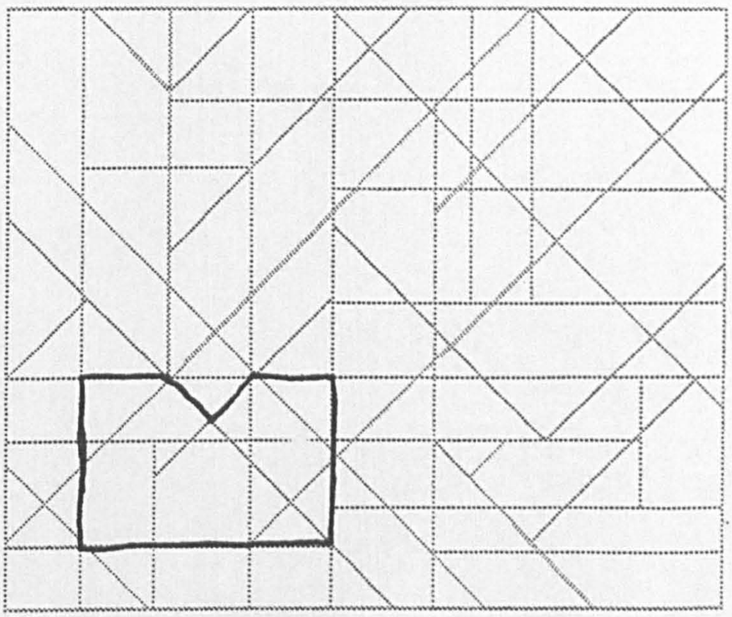


Find SHAPE A



Find SHAPE E



Find SHAPE F

APPENDIX-G (PAGES 301-309)

IMPROVED PRE-LABS USED DURING PHASE-II

APPENDIX-G

NAME ________________

PRE-LAB THE MICHELSON INTERFEROMETER

The following preparatory work for this experiment should be done **before you come to the lab.** Your demonstrator will check that this has been done.

What does it do ?

The Michelson Interferometer produces interference fringes between two beams of light which have travelled along different paths. These beams are created by division of amplitude at the beam splinter (Plate G_1). The interference pattern depends on the difference in the lengths of these paths.

The instrument can be used to measure small distances $\sim 10^{-10}$m, much smaller than anything visible to the naked eye or optical microscope. The micrometer in the instrument can only measure distances greater than about 10^{-5}m, but interference techniques are used to increase its sensitivity by 100,000.

What will I measure ?

You will measure:

(1) The average wave length of the sodium D lines.

(2) The spacing between the two wave lengths of the sodium D lines and

(3) The refractive index of air.

How does it work?

Read the appropriate section in the manual.

The 5:1 reduction lever is hinged at the left end so that, when the micrometer moves the right end by 5mm, mirror M1 moves by 1mm. Thus the distance moved by M1 equals the change in reading on the micrometer divided by 5.

What do I do ?

-Check that the lever ratio is 5:1.

-Obtain fringes with mercury light.

-Obtain fringes with white light. These occur when the path difference is 0. The compensating plate G_2 is essential for white light fringes as it equalises the path in glass for all wavelengths.

-Measure the average wave length of Sodium D lines, and their separation.

-Measure the refractive index of the air. The refractive index of the vacuum is 1 and the presence of air increases it very slightly.

What should I know before I begin ?

-How the Michelson Interferometer works

-The optical path length of a path through a transparent material is the length of vacuum containing the same number of wavelengths.

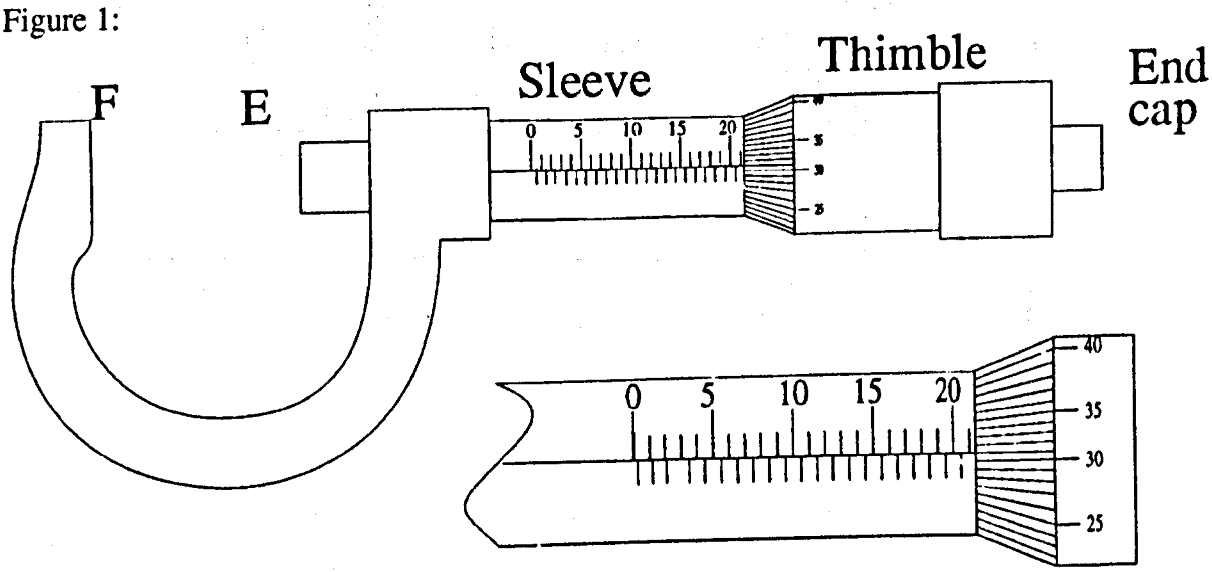
-How to read the micrometer scale (See the enclosed page. There are computer aided training packages on the Acorn network.)

-What is the accepted value of the wavelength of the sodium D lines ? ________

-What is the refractive index of air ? ________

MICROMETER SCREW GAUGE

Figure 1:



A typical micrometer is shown in figure 1.

The end cap, thimble and moving face E are connected and screwed into the sleeve of the instrument.

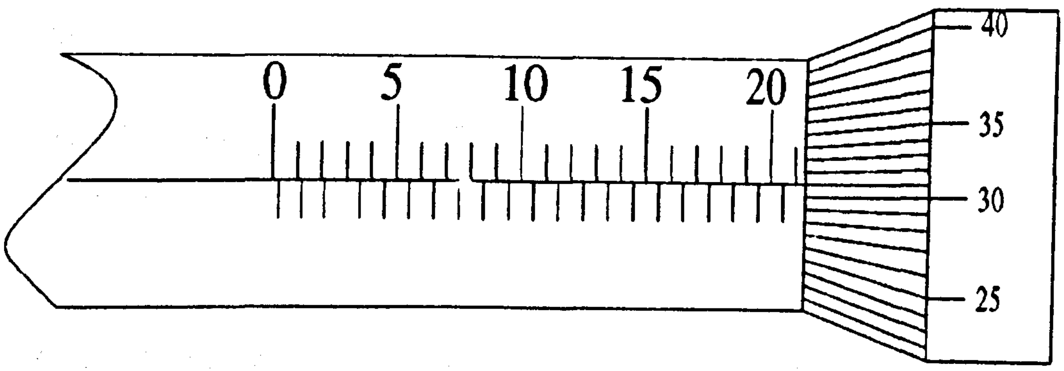
The object to be measured is placed in contact with face F, and face E moved into contact with it by turning the end cap. The thimble is connected to the end cap by a ratchet so that excessive force cannot be applied to the object.

The length of the object is equal to the length of datum line exposed by the thimble. The datum line is graduated with two sets of marks, the set above the line reading in mm and the set below reading in half mm. In the diagram, the reading is between 21.0mm and 21.5mm because the 21mm mark is visible but the 21.5 mark is hidden by the thimble.

The scale on the thimble gives decimal fractions of a mm. One complete revolution of the end cap corresponds to a movement of 0.5mm. The thimble scale is marked in 50 equal divisions, figured in five's so that each small division on the thimble represents 1/50 of 1/2mm which equals 1/100 mm (0.01mm). In the diagram, the datum line intersects the thimble scale at 31. The exact reading is then 21.31mm.

In figure 2, the main scale reading is more then 21.5 but less than 22.0. The thimble reading is again 31 so the total is 21.5 + 0.31 = 21.81mm.

Figure 2:



NAME ____________________

PRE-LAB DIFFRACTION AND INTERFERENCE, USING A LASER

The following preparatory work for this experiment should be **done before you come to the lab.** Your demonstrator will check that this has been done.

What does a laser do ?

The unique characteristics of light produced by laser make it suitable for many applications, for example: 1. welding 2. cutting 3. drilling 4. tracking 5. precision length measurement 6. velocity measurement 7. medical etc.

Why use it in this practical ?

Laser light contains only one wavelength which results in very sharp diffraction patterns. Other sources emit a range of wavelengths resulting in a blur of overlapping patterns. This characteristic of laser light make it ideal for the experimental study of diffraction and interference phenomena.

What is the point of this experiment ?

You will work with the diffraction and interference pattern from a single slit and from many slits. You will measure the wave length of light from the helium neon laser. You will study some of the properties of a hologram.

What is the experiment about ?

Read the description in the manual, and the relevant pages of Jenkins and White.

What will I be doing ?

Obtain the diffraction pattern from a single slit and use it to measure the wave length of the laser light. Do the same thing with several slits and gratings and compare your results with those obtained with the computer package **diffract.** Then investigate the properties of holograms.

What should I know before I begin ?

-You should be familiar with the principles of the operation of a laser.

-The characteristics of laser light which make it suitable for this experiment.

-You should be sufficiently familiar with the ideas of diffraction and interference to understand the experiment.

-**Hologram:** A hologram is a three dimensional image of an object stored on a photograph. It is produced by recording information about the phase difference between light scattered from a point on the object and a reference beam (phase=0). The phase of scattered light depends on the distance travelled which depends critically on the exact position of the point.

The path differences are large (many millions of wavelengths) so it is essential to use laser light which has a long ***coherence length*** (i.e. it can be regarded as a single, very long uninterrupted wave). Light from other sources has a short coherence length.

-(See Jenkins and White).

NAME ________________

PRE-LAB MECHANICAL OSCILLATOR AND RESONANCE

The following preparatory work for this experiment **should be done before you come to the lab**. Your demonstrator will check that this has been done. Make sure that the demonstrator shows you **how to use the oscilloscope.**

What should I expect to see in this experiment ?

You will see for yourself the behaviour of a resonating system especially how the amplitude of vibration increases dramatically when the frequency of an applied force matches the natural frequency of the system. You will discover how the phases of the oscillation and applied force are related. You will see how damping affects the motion of a vibrating system.

What will I be doing?

You will use the vibrating bar to plot a graph of amplitude versus the frequency of the applied force. This will show a resonance. Remember to label your axes.

You will use an oscilloscope to display two sine waves, one for the motion of the bar and one for the applied force. You can find the phase difference from the traces on the oscilloscope.

What equipment will I be using ?

Read the description in the lab manual.

You will use a variable frequency oscillator to drive a low impedance electro-mechanical vibrator which is coupled to a vibrating bar. The motion of the bar and vibrator are converted into electrical signals which are displayed on an oscilloscope.

In the second part of the experiment, an automated data acquisition system will produce results for electrical resonance.

What should I know before I begin ?

-What is meant by resonance?

-What is meant by phase and phase difference ?

-How do you recognise a resonance ?

-How do you damp the motion of the vibrating bar ?

-What is the relationship between frequency and angular frequency ?

- (See French: Vibration and Waves).

NAME ________________

PRE-LAB X-RAYS:

The following preparatory work for this experiment should **be done before you come to the lab.** Your demonstrator will check that this has been done.

What information can be obtained from x-rays ?

X-rays are used to determine the structure of crystals and molecules. The spectrum of x-rays emitted by an atom gives information about the structure of that atom.

Why use x-rays in this experiment ?

You are going to measure the inter atomic (or ionic) distances in a solid. To do this you have to use radiation, the wavelength of which is similar in size to the distances being measured. X-rays have a wavelength of suitable size.

What will I measure ?

(1) You will measure the distance between planes of ions in crystals of KCl and NaCl.

(2) You will obtain a spectrum of the x-rays emitted by Copper and study the absorption of x-rays by Nickel, Copper and Cobalt foils.

How does the spectrometer work ?

Read the description in the lab manual. X-rays from the Copper anode are passed through the slit to form a thin parallel beam, while x-rays striking the material on either side of the slit are absorbed. The beam of x-rays is then scattered by the layers of ions in the crystal. The intensity of scattered x-rays varies rapidly with the angle of incidence θ. When the Geiger counter detects an x-ray it gives out an electrical pulse. The rate meter is activated by these pulses and gives a reading in count/second.

Look at fig(b) "2-D ARRAY OF ATOMS" in the manual which shows several different arrangements of reflecting planes. The top row of atoms is the surface of the crystal. Only set d_1 is used in this experiment because the angle of incidence and angle of reflection are always measured from the surface of the crystal.

What will I be doing ?

-Using the crystals of LiF, plot a spectrum of counting rate against angle.

-Knowing the inter ionic spacing in LiF determine the wavelength of the K_α and K_β lines of copper.

-Measure the inter ionic spacing of KCl and NaCl.

-Plot spectra for KCl and NaCl. Knowing the wavelengths of the Copper K_α and K_β lines, you can measure the inter atomic spacing for these crystals.

-Obtain x-ray absorption spectra for Nickel, Copper and Cobalt.

What should I know before I begin ?

You should know:

-The value of inter ionic distance d_1 for LiF (Calculate it as described in the manual).

-What is meant by the term **spectrum.**

-**The Bragg conditions.** (See Walton. "Three phases of matter").

-What is meant by the term **angle of incidence** in optics and in x-ray diffraction, and how do their meanings differ.

APPENDIX-H (PAGES 310-320)

POST-LABS PREPARED AND USED DURING PHASE-II

APPENDIX-H

NAME _______________

POST-LAB LASERS

The following questions will help you to consolidate the work you did in the lab and help us to improve the lab manual. Please answer them carefully.

Tick the correct statements:

1. The diffraction pattern from a single slit is seen to get larger. This could be caused by:

   (a) The slit being made wider. True/false

   (b) The screen being moved further away from the slit. True/false

   (c) The wavelength being increased. True/false

2. Laser light is used in this experiment because:

   (a) Only a laser beam can have sufficient power.

   (b) Only a laser beam can be focused down to the size of the slit (S),

   (c) Only laser light consist of single sharp wave length.

   (d) Only laser light produces diffraction patterns.

3. To produce a hologram we may use

   (a) Any source of light.

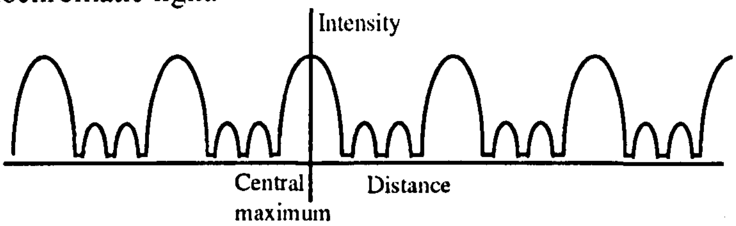
   (b) Only monochromatic light.

   (c) Only white light.

   (d) Only the laser beam.

4. Did you need instruction on how to read the Vernier scale on the travelling microscope? Yes/No.

5. The following pattern was obtained by illuminating a grating of several slits with monochromatic light.



How many slits are in the grating ? Answer is ___________

6. What is the essential physical property of light required to produce a hologram?

7. Look at a strong point source of light (not a laser) through the fabric of your handkerchief, and you will see an unusual pattern. Explain how it arises. What does it tell you about the cloth ? Write your explanation.

NAME: __________

POST-LAB X-RAYS

The following questions will help you to consolidate the work you did in the lab and help us to improve the lab manual. Please answer them carefully.

Tick the true statements:

1. (a) Photons of wave length 500nm are visible.

   (b) Photons of wave length 5000nm are x-rays.

   (c) Photons of wave length 5nm are x-rays.

   (d) Photons of wave length 0.005nm are x-rays.

2. (a) Photons of energy 2.5 ev are visible.

   (b) Photons of energy 25 ev are x-rays.

   (c) Photons of energy 250 ev are x-rays.

   (d) Photons of energy 0.025 ev are x-rays.

3. Sodium fluoride forms cubic crystals with lattice spacing 'a'. Tick the correct value for 'a'.

   (a) a=0.0023nm (b) a=0.023nm (c) a=0.23nm (d) a=2.3nm (e) a=23.0nm

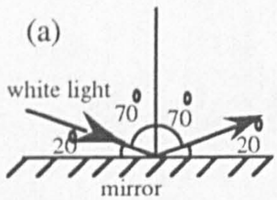
4. A beam of x-rays of intensity 1 is reduced to an intensity of 0.8 when it passes through 1mm of lead. If it passes through 2mm of lead, its intensity will be reduced to:

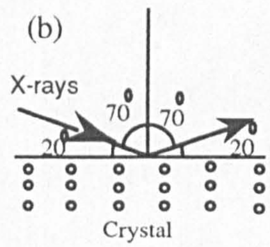
   (a) 0.6 (b) 0.64 (c) 0.5 (d) 0.7

5. An x-ray beam of unit intensity has its intensity reduced by 0.4 when passed through 2mm of Copper. When passed through 4mm of Copper its intensity is reduced by:

(a) 0.8 (b) 0.64 (c) 0.6 (d) 0.16.

6. Look at the figures (a) and (b) :

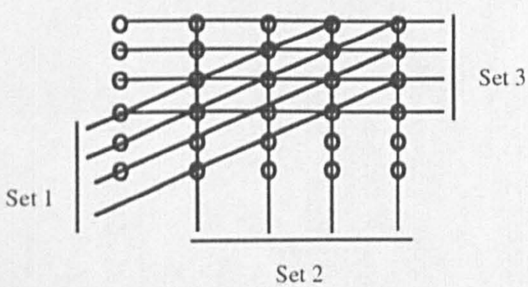




(a) What is the angle of incidence? (b) What is the angle of incidence?

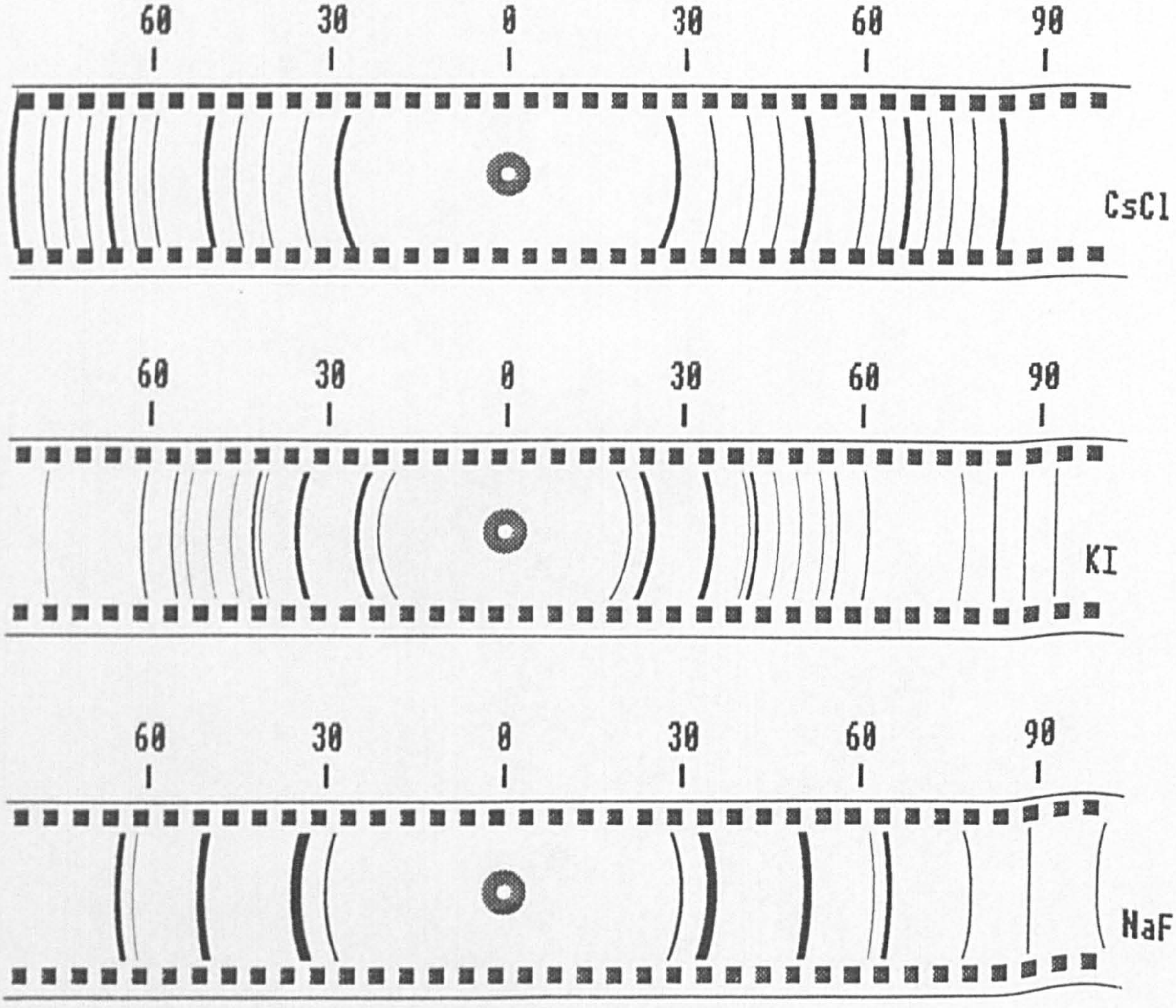
Answer is ____________ Answeris ______________

7. In diagram (b) above, which sets of crystal planes give Bragg reflection?



Tick the correct answer. (a)Set 1 (b)Set 2 (c)Set 3

8. In real life, it is often very difficult to obtain a single crystal suitable for use in a spectrometer. Instead, a powder photograph of very large number of minute crystals orientated at random can be used as the target. A few of these crystals will happen to be orientated correctly to satisfy the Bragg conditions for any set of planes. Cones of high intensity are formed with the original x-ray beam as axis. These are recorded on a photograph shown as under. Two crystals with the same structure give identical pattern of dark and faint lines, but the angular scale is different because the spacing is different.



What can you say about the structure of NaF.

(a) Same as the pattern for KI. (b) Same as the pattern for CsCl.

(c) Different from both of the above patterns (a) and (b).

NAME ________________

POST-LAB MECHANICAL OSCILLATOR AND RESONANCE

The following questions will help you to consolidate the work you did in the lab and help us to improve the lab manual. Please answer them carefully.

1. In a resonant system, the amplitudes of oscillation are A_o at low frequencies, A_r at resonance, and A_∞ at high frequencies. Write down these amplitudes in order of increasing size.

2. Why do we use the low impedance output of the oscillator?

3. Why do we use **integrating** amplifiers to increase the signals from the coil?

4. Did you need help to set-up the apparatus? Yes /No.

5. Did you need the help to use the oscilloscope? Yes /No.

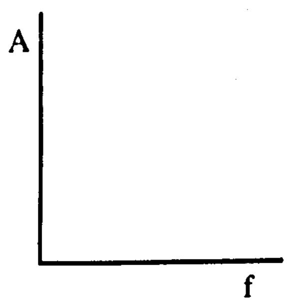
6. When water is irradiated with the higher energy end of the infrared spectrum, it absorbs strongly at a frequency of about 10^{14} H_z and hardly at all anywhere else. Why should this be so? If heavy water D_2O is used, the frequency absorbed moves to another fixed value. Why? Will this frequency be greater than or less than 10^{14} H_z ? Is water vapour a greenhouse gas?

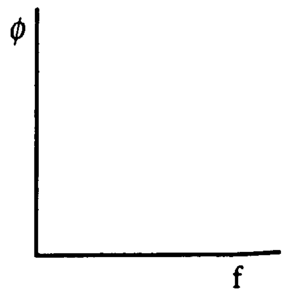
7. How do we reduce the oscillation set up in a car's suspension system?

8. A laser beam passes through smoked glass. The glass absorbs some of the light and the electric field (E) of the laser beam depends on distance (d) travelled through the glass according to $\sqrt{E} = Ae^{-\mu d}$.

What new variables would you choose to obtain a linear relation between them?

9. Complete the graphs below by drawing typical curves of amplitude (A) Vs frequency (f) and phase difference (ϕ) Vs frequency (f).





NAME ________________

POST-LAB MICHELSON INTERFEROMETER

The following questions will help you to consolidate the work you did in the lab and help us to improve the lab manual. Please answer them carefully.

1. In streets lit by sodium lamps, some car colours are changed. Which of the following statements are true. Tick the correct statements.

   (a) Yellow cars look yellow. (b) Blue cars look yellow.

   (c) Red cars look black. (d) White cars look yellow.

2. By using your lab manual estimate the thickness of this sheet of paper in terms of wave lengths of sodium light. Tick the best answer.

   (a) 50 wavelength. (b) 200 wavelength.

   (c) 800 wavelength. (d) 3200 wavelength.

3. Imagine that you blow gently through one of the arms of the M.I. What will happen to the fringe system?

4. The compensating plate G_2 is required with the particular version of the M.I used by you in the lab. Indicate whether the following statements are true or false.

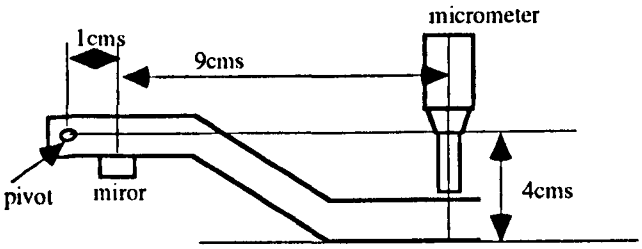
(a) The plate must be in place to obtain fringes with monochromatic light.

(b) The plate must be in place, to obtain fringes with white light.

(c) If the plate is not in place, no fringes will ever be observed regardless the nature of light used.

(d) The plate is not essential but improves the quality of the fringes.

5. What is the reduction ratio of the arrangement shown in the diagram?



Answer is ________

6. The two beams in the Michelson Interferometer are produced by ---

(a) division of wave front. (b) division of amplitude.

Answer (a) or (b) ______.

7. Did you obtain the white light fringes yourself? (Yes / No) or did you need help? (Yes / No).

8. At the beginning of the experiment were the mercury fringes already visible. (A) or did you obtain them yourself (Y) or did you require help (H)?

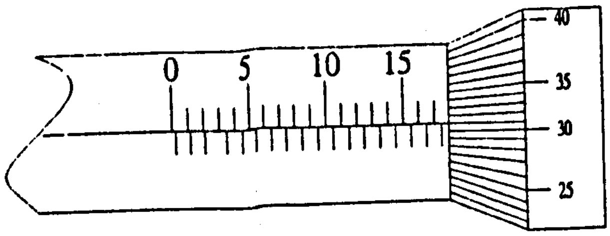
Answer A, Y, or H. _______.

9. Did you need help to read the micrometer? (Yes/ No).

10. A student makes the following measurements of a position of maximum intensity of the Sodium-D lines: 12.01, 11.99, 12.02, 11.98 and concludes that its position is 12.00. What is your answer?

11. Look at the following figures and answer the questions.

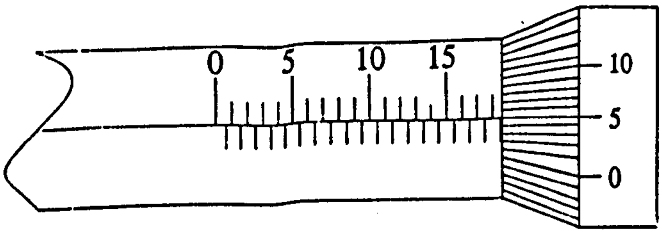
figure



(a) What is the reading in this figure?

Answer is ______________

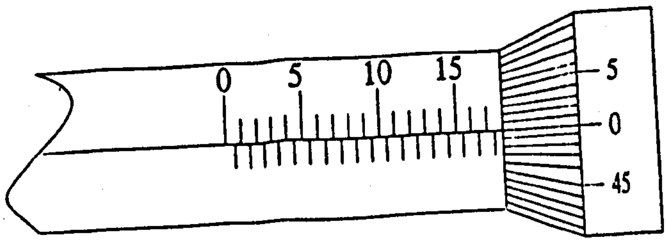
figure



(b) What is the reading in this figure?

Answer is ______________

figure



(c) What is the reading in this figure?

Answer is ______________